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Report of the

TECHNICAL CONSULTATION ON ACOUSTIC METHODS FOR FISH DETECTION AND ABUNDANCE ESTIMATION

Rapport de la

CONSULTATION TECHNIQUE SUR LES MÉTHODES ACOUSTIQUES DE DÉTECTION ET D'ESTIMATION DE L'ABONDANCE DU POISSON

Palma de Mallorca, Spain, 8-12 November 1982

Palma de Majorque, Espagne, 8-12 novembre 1982

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ORGANISATION DES NATIONS UNIES POUR L'ALIMENTATION ET L'AGRICULTURE

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GENERAL FISHERIES COUNCIL FOR THE MEDITERRANEAN (GFCM)
CONSEIL GENERAL DES PECHES POUR LA MEDITERRANEE (CGPM)

Report of the Technical Consultation on Acoustic Methods for Fish Detection and Abundance Estimation

Palma de Mallorca, Spain, 8-12 November 1982

Rapport de la Consultation technique sur les Méthodes acoustiques de détection et d'estimation de l'abondance du poisson

Palma de Majorque, Espagne, 8-12 novembre 1982

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ORGANISATION DES NATIONS UNIES POUR L'ALIMENTATION ET L'AGRICULTURE
Rome 1983

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PREPARATION OF THE PRESENT REPORT

The present text is the final version of the report approved by the Technical Consultation on Acoustic Methods for Fish Detection and Abundance Estimation.

PREPARATION DU PRESENT RAPPORT

Le présent texte constitue la version définitive du rapport approuvé par la Consultation technique sur les méthodes acoustiques de détection et d'estimation de l'abondance du poisson.

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ABSTRACT

The Technical Consultation on Acoustic Methods for Fish Detection and Abundance Estimation, which took place in Palma de Mallorca, Spain, from 8 to 12 November 1982, considered the situation of fish detection equipment in GFCM Member States, discussed standardization of measurements and reviewed the stocks assessed through acoustic methods. The Consultation included practical training and demonstration. It recommended that future work should be linked with ICES activities in this field, and a series of specific actions to be taken within GFCM and its subsidiary bodies.

RESUME

La Consultation technique sur les méthodes acoustiques de détection et d'estimation de l'abondance du poisson qui s'est tenue à Palma de Majorque, du 8 au 12 novembre 1982, a étudié les moyens destinés à la détection du poisson dans les Etats membres du CGPM, discuté la normalisation des mesures et passé en revue les stocks évalués par des méthodes acoustiques. Des démonstrations et une formation pratiques ont complété la Consultation. Il a été recommandé que les travaux ultérieurs soient menés en relation avec les activités du CIEM dans ce domaine; des actions spécifiques à entreprendre dans le cadre du CGPM et de ses organes subsidiaires ont également été proposées.

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I. INTRODUCTION

1. The Technical Consultation on Acoustic Methods for Fish Detection and Abundance Estimation took place in the Centro Costero de Baleares del Instituto Espanol de Oceanografía in Palma de Mallorca, from 8 to 12 November 1982, at the kind invitation of the Spanish Government.

2. Mr. M. Duran, Director of the Centre, welcomed the participants, the list of which is given in Appendix B.

3. On behalf of FAO, the Secretary of GFCM thanked the Spanish Authorities and in particular the Director of the Centre for having agreed to host again a meeting of the GFCM. He also welcomed the experts taking part in the Consultation including the observer from Portugal, a country which although not a member of GFCM is taking more and more part in its activities; Mr. Aglen from the Institute of Marine Research in Bergen who had processed the data collected by the research vessel DR. FRIDTJOF NANSEN in Tunisian and Algerian waters, and the representatives of the firm SIMRAD who had kindly agreed to put at the disposal of the participants an echo sounder signal simulator and other scientific acoustic equipment, and to demonstrate how they work.

4. The Agenda reproduced in Appendix A was approved.

5. Mr. P. Oliver was elected Chairman of the Consultation.

II. SUMMARY OF THE ICES/FAO SYMPOSIUM ON FISHERIES ACOUSTICS (Bergen, 21-24 June 1982)

6. The Technical Secretary introduced this subject. He stated that a copy of the report of the convenor and the 13 rapporteurs of the Symposium had not been obtained in time for the Consultation, and he therefore made a summary from memory.

7. The main conclusions reached at the Symposium were:

(a) Great progress had been made in electrical stability of the acoustic equipment, in particular in the integrator.

(b) The use of the two new standard targets was strongly recommended for the physical calibration of acoustic equipment and for intercalibration purposes. The hydrophone calibrations, unless carried out under completely controlled conditions, were considered unreliable.

(c) Studies of the tilt angle of fish and behaviour were considered essential.

(d) Better use should be made of available statistical methods.

(e) The knowledge of the distribution and behaviour of stocks should be used to determine the right time for biomass surveys.

(f) Better use should be made of all the information provided through the acoustic system.

(g) More absolute TS (target strength) values should be determined and exchanged.

(h) Comparisons between acoustic survey results and stock assessment by other methods led in many cases to good results.

(i) Biologists should become more involved in acoustic survey work, data analysis and reporting.

8. It was pointed out that negative judgements of acoustic surveys were due to a number of possible causes:

(a) Poor coverage in time and/or space

(b) Poor sampling, not enough fishing, particularly at night

(c) Poor reporting, drawing conclusions too quickly

(d) Poor calibration of equipment

9. Two publications will be produced: the report of the convenor and the rapporteurs, together with the four review papers will be published by ICES; FAO will publish a selection of the papers presented at the Symposium. The rapporteurs and chairmen have been involved in judging the relative importance of the papers. A publication of about 400 pages edited by O. Nakken and S.C. Venema, should appear in 1983.

10. The Technical Secretary also reported discussions that took place during the 70th Statutory Meeting of ICES held in October 1982. The ICES Working Group on Fish Behaviour will be expanded by incorporating specialists on acoustics. Every second year one or more acoustic topics should be discussed.

11. It was the opinion of the Consultation that participation in this enlarged Working Group would be useful to the acoustic scientific community not only of ICES member nations, but also from non-member nations of the Mediterranean area. It therefore recommended that work on fish detection and abundance estimation so far carried out within GFCM be in the future linked with the ICES activities in this field and that, for this purpose, membership of the ICES Working Group be also open to experts from non-ICES Member States.

12. The 70th Statutory Meeting of ICES also decided to present all acoustic papers under one Committee or in one joint meeting of interested Committees at the next ICES Statutory Meeting.

13. The attention was drawn to a paper prepared by N. Diner entitled: "Essai d'application de l'échointégration à la mesure de l'efficacité des chaluts", référence CIEM-C.M. 1982/B:12. Comité pour la capture des animaux marins, and to the many papers on joint acoustic surveys and the planning of such surveys.

14. The discussion concentrated on the paper No. 48 by Kjell Olsen et al., presented at the Symposium, entitled: "Observed fish reaction to a survey vessel with special reference to herring, cod and capelin". Mr. Aglen pointed out that due to tilt angle changes, live fish calibration results were probably not applicable in survey conditions where fish would be scared away by a passing vessel.

Various elements play a role in vessel avoidance, e.g., vessel noise related to speed, depth of the fish, fish size and swimming speed. Swimming speed was important for movements in horizontal direction, whereas tilt angle changes were important for vertical movements.

Sonar was considered useful to determine avoidance, while sensitivity of fish species to noise could be measured to some extent by comparing echograms and net-sounder recordings for various species. In the Adriatic, sprats were found to be relatively insensitive and sardines very sensitive, with anchovy occupying an intermediate position.

15. All these problems should not lead to discard acoustic surveys as impossible, but rather trigger further detailed research.

III. PRESENT SITUATION OF EQUIPMENT AND STAFF, AND PLANS FOR ACOUSTIC SURVEYS IN MEMBER STATES

16. Mr. Aglen explained in detail the Norwegian method of determining the calibration constant C, in particular the one used for the surveys in Tunisia and Algeria. The method is described in Appendix C.

17. In response to a request by the Technical Secretary, details of equipment and past and future cruises had been forwarded by France, Morocco and Spain (see Appendices D, E and F). Mr. Azzali provided information on Italy during the Consultation (see Appendix G).

18. Problems encountered with new equipment were briefly discussed, in particular the over-heating of the power supply of the EK-400 and QD which had been modified in the meantime.

19. The Consultation noted that the Portuguese vessel NORUEGA is equipped with a Situation Display Sonar, which is an excellent tool for behaviour studies on schools.

IV. TRAINING AND DEMONSTRATION

A. Simulator demonstration and exercises

20. The second day of the Consultation was dedicated entirely to the demonstration of the use of the echo sounder signal simulator provided by SIMRAD.

21. After a short introduction into the main parameters of acoustic assessment techniques by Mr. Brede, Mr. Borud explained the functions of the instrument on the hand of paper No. 56 presented at the Bergen Symposium "An echo sounder signal simulator for hydro-acoustic survey design and training", by Borud, Hansen and Johannessen.

22. The following exercises were done:

(a) Checking of EK-400 40 log R TVG function

(b) Calibrating the EK-400 by means of a reference target, TS = -33.7 dB

(c) Measuring fish target strength by means of the EK-400

(d) Measuring $\overline{SV}$ by means of the QD Digital Integrator

(e) Surveying the area indicated in a given map

23. A worksheet for the first exercise is given in Appendix H.

24. The exercises were followed with great attention and the usefulness of the simulator for training purposes at all levels was recognized. SIMRAD is now preparing a number of exercises that can be used as examples by instructors. An instructor familiar with acoustic techniques requires approximately one week training on the simulator.

25. Spain has already four of these simulators, viz. three in various schools in the Canary Islands and one in Vigo. These instruments are so far mainly used for the training of fishermen.

B. Use of standard sphere

26. The video tape "Everyman calibrations", prepared by K. Foote of the Marine Research Institute in Bergen was shown. In this tape the procedure of instrument calibration, determination of SL + VR, with a standard target, a copper sphere of 60 mm diameter, is demonstrated.

27. This type of instruction material was retained as an ideal training tool, in particular when it is given in combination with a real exercise, as during this Consultation, and participants expressed their thanks to Mr. Foote for having made the tape available to them.

28. The Consultation further felt it would also be useful to have a copy of the text of the video film, and in particular of the large number of equations shown.

29. Mr. P. Oliver introduced the paper by himself and Juan Miquel "Calibration of hydro-acoustic equipment used to evaluate fish biomasses by using elastic and solid spheres" (see Appendix I). A computer program for calculations of α, based on oceanographic conditions encountered during the experiment, is also given. Copies of these programs can be obtained from the research centre in Palma.

30. The depth in quiet waters, without waves and currents, required for the calibration with the copper sphere is at least 20 m in most cases. In several areas it is difficult to find this situation and the use of a sphere with a lower TS may therefore be recommended. Work to produce a standard copper sphere has already been initiated in Norway.

31. It was stressed that the use of a standard target should not fully exclude the use of hydrophones, since these instruments can give more detailed information on the transmitter and receiver performance.

C. On board calibration exercises

32. A day trip with the research vessel ODON DE BUEN of the Centro Costero de Baleares of the IEO was organized to a quiet bay of the Cabrera island to execute calibration exercises with the standard copper sphere (diameter 60 mm, TS = -33.7 dB) and the tungsten carbide sphere (diameter 38.1 mm, TS = -42.3 dB) provided by Morocco.

33. Before starting the actual exercise, Mr. Brede showed the procedure to be followed on the hand of another worksheet prepared by SIMRAD.

34. The copper sphere was then brought into position, and the correct methodology of finding the right position for the sphere, in the centre of the beam, was explained. First a calculation had been made of the approximate reading to be expected on the oscilloscope, in order to avoid that the sphere would be centralized under a side lobe.

35. The checking of all vital functions of the system was stressed and in fact the functioning of the TVG system was found not to be according to specifications.

36. The results obtained with the two spheres were identical, but the end values for SL + VR cannot be used due to the problem mentioned above. The results are given in Appendices J and K. The values for the sum of SL + VR of around 112 dB, are much lower than the theoretically obtainable value of 120 dB. This indicates that something is wrong with the nickel transducer. The use of a ceramic transducer, and a special steel pipe to separate the transducer cable from other cables was recommended. Problems caused by the high electric noise level of the vessel were also discussed. Since this noise level limits the performance of the vessel to a very large extent, remedial measures were recommended before executing any further major survey.

37. The results of the last survey with the research vessel ODON DE BUEN should be processed taking into account the actual TVG deviations.

38. The shiny tungsten carbide sphere seemed to attract more fish than the copper sphere. Unfortunately the measurements with the tungsten carbide sphere were done in a slightly different location, so that the appearance of fish cannot exclusively be attributed to the use of the shiny sphere. After each movement of the sphere fish seemed to approach it. A less shiny appearance might therefore be recommendable if that can be achieved without disturbing the standard target strength.

D. Demonstration of the QD 200

39. A demonstration was given of a new instrument for a in situ measurement of fish target strength distribution (QD 200) after a short introduction by Mr. Brede, based on Contribution No. 54 of the Bergen Symposium by Solli, Brede and Lindem entitled "A new instrument for in situ measurement of fish target strength distribution".

E. ALSAREV 82

40. An excellent video tape produced during the survey with the research vessel CORNIDE DE SAAVEDRA in the Alboran Sea was shown. It was found to be particularly useful for giving a wide audience an insight in the operations of an acoustic survey and the running of a large research vessel in general. Copies of the tape could be made available - on request - by the Balearic Centre of the IEO.

V. LIVE FISH CALIBRATION AND INTER-CALIBRATION

A. Live fish calibration

41. Mr. Azzali presented a thorough review of live fish calibration techniques, including the formulas used by a number of scientists and stressing the short-comings of the system. This paper is presented in Appendix L.

42. The behaviour of the fish in the cage was also demonstrated through a number of photographs of Spanish experiments, which showed that the fish kept a distance of about 20 cm from the sides of the cage. Attention was drawn to the work of Guzman, who had obtained good results by changing the shape of the cage.

43. Target strength could vary a lot depending on the bahaviour, defined as wild, livery and quiet. The variance of target strength measurements is much greater in the case of wild fish than with quiet fish.

44. Suggestions were made to do experiments in much larger keep nets or ponds with a known quantity of fish and to move the transducer over the entire surface. In fact a reservoir in Mallorca where each year a known quantity of fish is introduced could be used for such experiments.

B. Inter-calibration

45. Mr. Pastor introduced the paper entitled: "Obtaining echo integrator inter-calibration coeffi-cents by joint navigation of research vessels" (see Appendix M). The paper reports inter-calibration between the research vessels CORNIDE DE SAAVEDRA, FRIDTJOF NANSEN, and NORUEGA. The results were satisfactory in all cases.

46. It was pointed out that noise levels should always be measured and that inter-calibration under noise conditions as prevailing during normal survey operations was in fact better than inter-calibration by means of a standard sphere.

47. A homogeneous mud bottom is a good target for inter-calibration, provided identical transducers are being used. Special care should be taken to avoid saturation of the equipment.

48. Inter-calibration between a 120 kHz and a 38 kHz sounder had proved to be difficult, in particular when a lot of plankton was present. In tropical areas plankton is recorded much better by a 38 kHz sounder and it was therefore considered advisable to carry out surveys under such conditions with a 120 kHz sounder, when depths would not exceed 120 m.

49. Also for inter-calibration exercises a thorough check-up of all equipment was strongly recommended.

VI. REVIEWS OF STOCKS ASSESSED ACOUSTICALLY

A. Adriatic

50. Mr. Azzali explained the situation in the Adriatic Sea and the coverage problems encountered, due to the movements of the stocks of sardines, anchovies and sprat between Italian and Yugoslav waters. Since Yugoslavia only carries out relative measurements, by comparing more readings obtained during yearly surveys along the same track, it has not been possible to obtain a total biomass estimate for the whole area. The only biomass figures obtained for the whole area are those based on egg and larvae surveys, which indicate biomass levels several times higher than those obtained from acoustic surveys.

51. The best solution to the problem of inter-calibration is to use a standard target for Italian and Yugoslav vessels after thorough electrical calibration. The results of Italian and Yugoslav surveys could then be added, provided the coverage in time and space is adequately adjusted, and thus an overall estimate could be obtained.

52. Mr. Kacic made a brief statement regarding Yugoslav research.

53. Messrs. Azzali and Kacic agreed to produce a joint report using the C value obtained in Italy, corrected for the differences in equipment performance as determined by electrical calibration, in order to get a preliminary idea of the magnitude of the resources. This report will be made available to the GFCM Technical Consultation on Stock Assessment in the Adriatic to be held in Fano, in June 1983.

B. Alboran Sea

54. The research vessels CORNIDE DE SAAVEDRA and IBN SINA surveyed respectively the Spanish (see Appendix N) and the Moroccan 1/ sides of the Alboran Sea in May 1982. The preliminary reports were introduced by Messrs. Pastor and Bencherifi.

55. The Moroccan data are being processed. The methodology followed is given in Contribution No. 92 by Lamboeuf et al., of the Bergen Symposium entitled: "Acoustic biomass estimates of sardine stocks in Morocco, from 1979 to 1981".

56. Spain used for the first time a method described by Dommarnes and Nakken to separate age groups of sardines. The otolith readings would have to be revised, since a method had not been established. The sonar had been used by both vessels, but the recordings of the CORNIDE DE SAAVEDRA had not yet been processed. Since both vessels inter-calibrated against the research vessel FRIDTJOF NANSEN, an indirect inter-calibration should be possible.

57. Since for the first time a full coverage of the Alboran Sea has been achieved, the Consultation recommended that every effort should be made to produce either a joint report, or separate reports that would be directly comparable, in particular the distribution maps of the various species and totals of the biomass by species.

58. Morocco now plans to execute a survey in the Alboran Sea every year in spring.

59. The Consultation recommended that Spain should try and make a similar cruise at the same period in order to obtain a continuous full coverage.

VII. FUTURE ACTIVITIES

60. Realizing the need for close contacts and collaboration with advanced acoustic centres and experts in Europe, the Consultation recommended, as stated in paragraph 11 of this report, that acoustic experts of GFCM could become members of the future ICES Working Group on Fish Behaviour and Acoustics.

61. The GFCM Secretariat was requested to investigate with the ICES Secretariat whether this would be feasible. If not, the Consultation decided that acoustic activities should be continued within GFCM. If another consultation was to be organized, Mr. Bencherifi extended an invitation to hold it in Morocco.

62. The Consultation pointed out that, in any case, problems regarding acoustic research and related administrative problems would continue to be discussed within GFCM, either during its sub-regional consultations on stock assessment, its Committee on Resource Management, its main sessions or on other occasions.

63. The Consultation also recognized that further training was necessary at all levels and recommended that efforts be made by FAO to provide additional training facilities.

VIII. ADOPTION OF THE REPORT

64. The Report of the Technical Consultation on Acoustic Methods for Fish Detection and Abundance Estimation was adopted on 12 November 1982.

65. At the closure of the session, participants expressed their warmest thanks to the host country, the Director of the IEO and his staff, and Messrs. Brede and Borud for their invaluable contribution to the Consultation.

1/ The report of this survey will be published in the series "Travaux et documents" of the "Institut des pêches maritimes du Royaume du Maroc".

I. INTRODUCTION

1. La Consultation technique sur les méthodes acoustiques de détection et d'estimation de l'abondance du poisson a eu lieu au Centro Costero de Baleares del Instituto Espanol de Oceanografía (IEO) à Palma de Majorque, du 8 au 12 novembre 1982 à l'aimable invitation du Gouvernement espagnol.

2. M. M. Duran, directeur du Centre a accueilli les participants dont la liste figure à l'annexe B.

3. Le Secrétaire du Conseil général des pêches pour la Méditerranée (CGPM) a remercié, au nom de la FAO, les autorités espagnoles et en particulier le directeur du Centre, d'avoir bien voulu accueillir à nouveau une réunion du CGPM. Il a également souhaité la bienvenue aux experts qui prenaient part à la consultation y compris un observateur du Portugal - pays qui participe de plus en plus aux activités du CGPM bien qu'il n'en soit pas membre - M. Aglen de l'Institut de recherche marine de Bergen qui a traité des données recueillies par le navire de recherche "DR. FRIDTJOF NANSEN" dans les eaux tunisiennes et algériennes, et les représentants de la Société SIMRAD qui a aimablement accepté de mettre à la disposition des participants un simulateur de signal d'écho-sondeur et autre équipement acoustique, et de faire la démonstration de leur fonctionnement.

4. L'ordre du jour qui figure à l'annexe A a été approuvé.

5. M. P. Oliver a été élu président de la consultation.

II. RESUME DU SYMPOSIUM CIEM/FAO SUR LES METHODES ACOUSTIQUES (Bergen, du 21 au 24 juin 1982)

6. En présentant ce sujet, le Secrétaire technique a déclaré qu'il n'avait pas été possible d'obtenir à temps pour la Consultation le rapport de l'organisateur et des rapporteurs du Symposium et qu'il allait donc en faire un résumé de mémoire.

7. Les principales conclusions du Symposium sont les suivantes:

(a) de grands progrès ont été réalisés dans la stabilité électrique de l'équipement acoustique, en particulier de l'intégrateur;

(b) l'utilisation de deux nouvelles cibles normalisées a été fortement recommandée pour l'étalonnage physique du matériel acoustique et pour l'inter-étalonnage. L'étalonnage par hydrophone n'est pas fiable, à moins qu'il soit effectué dans des conditions totalement contrôlées;

(c) il est indispensable de procéder à des études de l'angle d'inclinaison du poisson et de son comportement;

(d) il faudrait faire une meilleure utilisation des méthodes statistiques actuelles;

(e) il faudrait se fonder sur la connaissance de la répartition et du comportement des stocks pour déterminer le moment opportun pour effectuer des enquêtes sur la biomasse;

(f) il faudrait utiliser plus rationnellement toutes les informations obtenues grâce au système acoustique;

(g) il faudrait déterminer et échanger un plus grand nombre de valeurs absolues de l'indice de réflexion de la cible (TS en anglais);

(h) les comparaisons entre les résultats des prospections acoustiques et l'évaluation des stocks par d'autres méthodes on très souvent donné de bons résultats;

(i) les biologistes devraient participer plus activement aux prospections acoustiques, à l'analyse des données et à l'établissement des rapports.

8. Les jugements négatifs sur les prospections acoustiques tiennent probablement à la médiocrité:

(a) de la couverture dans le temps et/ou dans l'espace;

(b) de l'échantillonnage, et de la pêche, particulièrement la nuit;

(c) des rapports tirant des conclusions trop hâtives;

(d) de l'étalonnage du matériel.

9. Deux documents seront publiés: le rapport de l'organisateur et des rapporteurs ainsi que les quatre documents de travail seront publiés par le CIEM; la FAO publiera un choix des documents présentés au Symposium. Les rapporteurs et les présidents ont participé à l'estimation de l'importance relative de ces documents. Un ouvrage d'environ 400 pages, préparé par O. Nakken et S.C. Venema devrait paraître en 1983.

10. Le Secrétaire technique a également commenté les débats qui ont eu lieu lors de la 70ème réunion statutaire du CIEM en octobre 1982. Le Groupe de travail du CIEM sur le comportement des poissons s'enrichira de spécialistes de l'acoustique et débattra, tous les deux ans, d'un ou de plusieurs thèmes ayant trait à l'acoustique.

11. La Consultation estime que la participation à ce Groupe de travail élargi serait utile à la communauté scientifique acoustique non seulement des Etats Membres du CIEM, mais également des pays non membres appartenant à la région méditerranéenne. Elle a donc recommandé que les activités de détection et d'estimation de l'abondance du poisson, menées jusqu'ici au sein du CGPM, soient à l'avenir liées aux travaux du CIEM dans ce domaine et qu'à cet effet, le Groupe de travail du CIEM soit également ouvert à des spécialistes d'Etats non membres du CIEM.

12. Lors de la soizante-dixième réunion statutaire, le CIEM a également décidé de présenter toutes les communications sur les techniques acoustiques au sein d'un même comité ou au cours d'une réunion mixte des comités intéressés lors de la prochaine réunion statutaire CIEM.

13. L'attention a été appelée sur un document de N. Diner, intitulé: Essai d'application de l'échointégration à la mesure de l'efficacité des chaluts", référence CIEM-C.M. 1982/B:12. Comité pour la capture des animaux marins et sur les nombreux documents concernant les prospections acoustiques conjointes et leur planification.

14. Les débats se sont concentrés sur la communication N° 48 de Kjell Olsen et al. présentée au Symposium et intitulée "Observed fish reaction to a survey vessel with special reference to herring, cod and capelin". M. Aglen a fait remarquer qu'en raison des variations de l'angle d'inclinaison, les résultats de l'étalonnage avec des poissons vivants n'étaient probablement pas applicables aux prospections où le passage du navire fait fuir le poisson.

Différents éléments jouent un rôle dans la fuite du poisson: le bruit du navive qui est lié à sa vitesse, la profondeur à laquelle se trouve le poisson, la taille du poisson et sa vitesse de nage. Cette dernière est importante pour les mouvements en direction horizontale tandis que les variations de l'angle d'inclinaison le sont pour les mouvements verticaux.

Le sonar permet de déterminer la mesure dans laquelle le poisson fuit le navire, tandis que la sensibilité de l'espèce de poisson au bruit peu être mesurée jusqu'à un certain point en comparant les échogrammes et les enregistrements du netzsonde pour différentes espèces. Dans l'Adriatique, on a observé que les sprats étaient relativement insensibles et que les sardines l'étaient beaucoup, les anchois occupant une position intermédiaire.

15. Tous ces problèmes ne devraient pas conduire à écarter les prospections acoustiques comme impossibles mais plutôt à approfondir les recherches.

III. SITUATION ACTUELLE DU MATERIEL ET DU PERSONNEL ET PLANS DE PROSPECTIONS ACOUSTIQUES DANS LES ETATS MEMBRES

16. M. Aglen a expliqué en détail la méthode norvégienne de détermination de la constante d'étalonnage C, en particulier celle utilisée pour les prospections en Tunisie et en Algérie. La méthode est décrite à l'annexe C.

17. En réponse à une demande du Secrétaire technique, la France, le Maroc et l'Espagne ont envoyé des informations sur le matériel et sur les prospections passées et futures (voir annexes D, E et F). M. Azzali a donné des informations sur l'Italie au cours de la Consultation (voir annexe G).

18. Les problèmes posés par le nouveau matériel ont été brièvement étudiés, en particulier la surchauffe du dispositif d'alimentation de l'EK400 et QD qui a été modifié entre-temps.

19. La Consultation a pris note que le navire portugais "NORUEGA" est équipé d'un sonar avec écran de visualisation qui constitue un excellent instrument d'étude du comportement des bancs de poisson.

IV. FORMATION ET DEMONSTRATIONS

A. Démonstration du simulateur et exercices

20. La seconde journée de la Consultation a été entièrement consacrée à la démonstration de l'utilisation du simulateur de signal d'écho-sondeur fourni par SIMRAD.

21. Après une courte présentation des principaux paramètres des techniques d'évaluation acoustique par M. Brede, M. Borud a expliqué à quoi sert l'appareil en s'appuyant sur le document N° 56 présenté au Colloque de Bergen intitulé "An echo sounder signal simulator for hydro-acoustic survey design and training", par Borud, Hansen et Johannessen".

22. Les exercices suivants ont été effectués:

(a) vérification du EK400 40 log R fonction GVT;

(b) étalonnage du EK400 au moyen d'une cible de référence, TS = -33,7 dB;

(c) mesure de l'indice de réflexion du poisson-cible à l'aide du EK400;

(d) mesure de $\overline{SV}$ à l'aide de l'intégrateur digital QD;

(e) prospection de la zone indiquée sur une carte donnée.

23. La procédure à suivre pour le premier exercice est donnée à l'annexe H.

24. Les exercices ont été suivis avec une grande attention et l'utilité du simulateur aux fins de la formation à tous les niveaux a été reconnue. SIMRAD prépare actuellement un certain nombre d'exercices qui peuvent être utilisés comme exemples par les instructeurs. Un instructeur familier des techniques acoustiques aura besoin d'environ une semaine de formation sur le simulateur.

25. L'Espagne possède déjà quatre de ces simulateurs, trois dans différentes écoles des îles Canaries et un à Vigo. Jusqu'ici, ces instruments sont utilisés essentiellement pour la formation des pêcheurs.

B. Utilisation de la sphère normalisée

26. Le film sur bande magnétique intitulé "Everyman calibrations" réalisé par K. Foote, de l'Institut de recherche marine de Bergen, a été projeté. Il illustre la démonstration de l'étalonnage d'instruments, de la détermination de SL + VR, avec une cible normalisée - une sphère de cuivre de 60 mm de diamètre.

27. Ce type de matériel didactique est considéré comme un instrument de formation idéal, en particulier lorsque son utilisation va de pair avec un exercice réel, comme cela a été le cas au cours de cette consultation, et les participants ont remercié M. Foote de leur avoir présenté ce film.

28. La Consultation a en outre estimé qu'il serait utile d'avoir le texte du film video et en particulier les nombreuses équations qu'il contient.

29. M. P. Oliver a présenté le document qu'il avait préparé en collaboration avec Juan Miquel intitulé "Calibration of hydroacoustic equipment used to evaluate fish biomasses by using elastic and solid spheres" (voir annexe I). Il a donné également un programme informatisé pour le calcul de α sur la base des conditions océanographiques dans lesquelles se déroule l'expérience. On peut se procurer un exemplaire de ces programmes auprès du Centre de recherche de Palma.

30. L'étalonnage à l'aide de la sphère de cuivre, en eaux tranquilles sans vagues ni courants, a lieu dans la plupart des cas à vingt mètres au moins de profondeur. Il est souvent difficile, dans certaines régions, de trouver ces conditions et l'on peut donc recommander d'utiliser une sphère dont l'indice de réflexion est plus faible. Les travaux nécessaires à la fabrication d'une sphère de cuivre normalisée ont déjà commencé en Norvège.

31. On a souligné que l'utilisation d'une cible normalisée ne devrait pas exclure entièrement l'utilisation des hydrophones, car ces derniers peuvent donner des informations très détaillées sur les performances de l'émetteur et du récepteur.

C. Exercices d'étalonnage à bord

32. Une sortie d'un jour avec le navire de recherche "ODON DE BUEN" du Centro costero de Baleares de l'IEO a été organisée dans une baie tranquille de l'île de Cabrera en vue de procéder à des exercices d'étalonnage avec la sphère de cuivre normalisée (diamètre 60 mm, TS = -33,7 dB) et la sphère au carbure de tungstène (diamètre 38,1 mm, TS = -42,3 dB) fournie par le Maroc.

33. Avant de commencer l'exercice lui-même, M. Brede a montré la procédure à suivre sur la base d'autres instructions préparées par SIMRAD.

34. Il a ensuite mis en place la sphère de cuivre et expliqué la méthode à suivre pour trouver la bonne position de la sphère au centre du faisceau. La mesure approximative à laquelle il fallait s'attendre sur l'oscilloscope avait d'abord été calculée de façon à éviter de placer le centre de la sphère sous un lobe secondaire.

35. Il a ensuite insisté sur la vérification de toutes les fonctions essentielles du système et, en fait, le fonctionnement du système GVT (gain variable dans le temps) s'est révélé ne pas être conforme aux spécifications.

36. Les résultats obtenus avec les deux sphères étaient identiques mais les valeurs finales de SL + VR ne peuvent être utilisées en raison du problème mentionné ci-dessus. Les résultats sont donnés aux annexes J et K. Les valeurs de la somme (SL + VR) d'environ 112 dB sont de beaucoup inférieures à la valeur de 120 dB que l'on peut théoriquement obtenir. Le transducteur en nickel ne fonctionne donc pas normalement. On a recommandé d'utiliser un transducteur en porcelaine et un tuyau d'acier spécial pour séparer le câble du transducteur des autres câbles. Les problèmes causés par le niveau élevé des bruits électriques du navire ont également été étudiés. Le bruit limitant considérablement les performances du navire, on a recommandé d'adopter des mesures pour y remédier avant d'entreprendre une nouvelle prospection.

37. Les résultats de la dernière prospection du navire de recherche "ODON DE BUEN" devraient être dépouillés en tenant compte des écarts réels du GVT.

38. La sphère de carbure de tungstène, qui est brillante, semble attirer plus de poisson que la sphère de cuivre. Malheureusement, les mesures à l'aide de la sphère de carbure de tungstène ont été faites dans un endroit légèrement différent de sorte que l'apparition du poisson ne peut être attribuée exclusivement à l'utilisation d'une sphère brillante. Après chaque mouvement de la sphère le poisson semblait s'en approcher. Il pourrait donc être souhaitable d'utiliser une sphère moins brillante si toutefois cela ne modifie pas l'indice de réflexion de la cible de référence.

D. Démonstration du QD 200

39. Après une courte présentation par M. Brede, sur la base de la contribution N° 54 du Colloque de Bergen intitulée "A new instrument of in situ measurements of fish target strength distribution" par Solli, Brede et Lindem, on a procédé à la démonstration d'un nouvel instrument pour la mesure in situ de la répartition de l'indice de réflexion de la cible (QD200).

E. ALSAREV 82

40. Un excellent film video réalisé au cours de la prospection effectuée par le navire de recherche "CORNIDE DE SAAVEDRA" dans la mer d'Alboran, a ensuite été projeté. On a ainsi pu donner à de nombreux spectateurs une idée des opérations que comporte la prospection acoustique et l'exploitation d'un grand navire de recherche en général. On peut se procurer des exemplaires du film auprès du Centre des Baléares de l'IEO sur demande.

V. ETALONNAGE ET INTER-ETALONNAGE AVEC DES POISSONS VIVANTS

A. Etalonnage avec des poissons vivants

41. M. Azzali a présenté une étude approfondie des techniques d'étalonnage avec des poissons vivants, notamment des formules utilisées par un certain nombre de scientifiques, et a souligné les défauts du système. Cette communication figure à l'annexe L.

42. Il a également fait une démonstration du comportement des poissons dans la cage à l'aide d'un certain nombre de photographies sur les expériences faites par les Espagnols qui montraient que le poisson se maintenait à une distance d'environ 20 cm des parois de la cage. L'attention a été appelée sur les travaux de Guzman qui a obtenu de bons résultats en modifiant la forme de la cage.

43. L'indice de réflexion de la cible peut varier considérablement selon le comportement qui est défini désordonné, actif ou tranquille. La variance des mesures de l'indice de réflexion de la cible est beaucoup plus grande dans le cas de poissons ayant un comportement désordonné que dans celui des sujets qui ont un comportement tranquille.

44. On a suggéré de procéder à des expériences dans des cages en filets ou dans des réservoirs beaucoup plus grands contenant une quantité connue de poissons et de déplacer le transducteur sur toute la surface. En fait, on pourrait utiliser à cette fin un réservoir situé à Majorque où l'on introduit chaque année une quantité connue de poissons.

B. Inter-étalonnage

45. M. Pastor a présenté la communication intitulée: "Obtaining echo integrator intercalibration coefficients by joint navigation of research vessels" (voir annexe M). Cette communication traite de l'inter-étalonnage entre les navires de recherche "CORNIDE DE SAAVEDRA", "FRIDTJOF NANSEN" et "NORUEGA". Les résultats ont été satisfaisants dans tous les cas.

46. On a fait remarquer que le niveau du bruit devrait toujours être mesuré et qu'il était préférable en fait de procéder à l'inter-étalonnage dans le bruit habituel des opérations normales de prospection plutôt qu'au moyen d'une sphère normalisée.

47. Un fond boueux homogène est une bonne cible pour l'inter-étalonnage pourvu que l'on utilise des transducteurs identiques. Il faut veiller à éviter la saturation du matériel.

48. L'inter-étalonnage entre des sondeurs de 120 kHz et de 38 kHz s'est révélé difficile, en particulier en présence d'une grande quantité de plancton. Dans les zones tropicales, la présence de plancton est enregistrée beaucoup mieux par un sondeur de 38 kHz; il a donc été considéré souhaitable d'effectuer les prospections dans ces conditions avec un sondeur de 120 kHz quand les profondeurs n'excèdent pas 120 m.

49. On a également recommandé, pour ces exercices d'inter-étalonnage, de vérifier soigneusement tout l'équipement.

VI. ETUDE DES STOCKS EVALUES PAR LA METHODE ACOUSTIQUE

A. Adriatique

50. M. Azzali a parlé de la situation dans l'Adriatique et des problèmes de couverture que posent les mouvements des stocks de sardines, d'anchois et de sprats entre les eaux italiennes et yougoslaves. Puisque la Yougoslavie n'effectue que des mesures relatives, en comparant plusieurs résultats obtenus au cours des prospections annuelles le long du même couloir, il n'a pas été possible d'obtenir une estimation de la biomasse totale pour toute la région. Les seuls chiffres de biomasses qu'on a pu se procurer pour toute la région sont ceux qui sont fondés sur les prospections des oeufs et des larves qui donnent des niveaux de biomasses plusieurs fois supérieurs à ceux obtenus avec des prospections acoustiques.

51. La meilleure solution au problème de l'inter-étalonnage consiste à utiliser une cible normalisée pour les navires italiens et yougoslaves après un étalonnage électrique soigneux. On pourrait ensuite ajouter les résultats des prospections italiennes et yougoslaves, pourvu que la couverture dans le temps et dans l'espace soit ajustée comme il convient, et obtenir ainsi une estimation globale.

52. M. Kacic a fait un bref exposé sur la recherche yougoslave.

53. MM. Azzali et Kacic ont décidé d'établir un rapport conjoint utilisant la valeur C obtenue en Italie, corrigée des différences de performance du matériel telles qu'elles sont établies par étalonnage électrique, de façon à avoir une idée préliminaire de l'ampleur des ressources. Ce rapport sera distribué lors de la Consultation technique du CGPM sur l'évaluation des stocks dans l'Adriatique qui se tiendra à Fano en juin 1983.

B. Mer d'Alboran

54. Les navires de recherche "CORNIDE DE SAAVEDRA" et "IBN SINA" ont prospecté respectivement les rives espagnoles et marocaines (voir Annexe N) 1/ de la mer d'Alboran en mai 1982. Les rapports préliminaires ont été présentés par MM. Pastor et Bencherifi.

55. Les données de la prospection marocaine sont en cours de traitement. La méthodologie suivie est donnée dans la communication N° 92 du Colloque de Bergen intitulée "Acoustic biomass estimates of sardine stocks in Morocco from 1979 to 1981", par Lamboeuf et al.

56. L'Espagne a utilisé pour la première fois une méthode décrite par Dommasnes et Nakken pour séparer les sardines par groupe d'age. Les observations des otolithes devront être révisées puisqu'une méthode n'avait pas été établie. Le sonar a été utilisé par les deux navires mais les enregistrements du "CORNIDE DE SAAVEDRA" n'ont pas encore été interprétés. Etant donné que les deux navires ont procédé à un inter-étalonnage avec le navire de recherche "DR. FRIDTJOF NANSEN", on devrait pouvoir procéder à un inter-étalonnage indirect.

57. Comme c'est la première fois que l'on obtient une couverture totale de la mer d'Alboran, la Consultation a recommandé de s'efforcer d'établir, soit un rapport commun, soit des rapports séparés qui seraient directement comparables, notamment pour ce qui est des cartes de répartition des différentes espèces et du total de la biomasse par espèces.

58. Le Maroc a maintenant décidé de procéder à une prospection de la mer d'Alboran chaque année au printemps.

59. La consultation a recommandé que l'Espagne s'efforce d'effectuer une prospection analogue à la même période de façon à obtenir une couverture totale continue.

1/ Le rapport de cette prospection sera publié dans la série "Travaux et documents" de l'"Institut des pêches maritimes" du Royaume du Maroc.

VII. ACTIVITES FUTURES

60. Estimant indispensable d'établir une collaboration et des contacts étroits avec les centres et les experts de haut niveau des méthodes acoustiques en Europe, la Consultation a recommandé - comme indiqué au paragraphe 11 de ce rapport - que les spécialistes des techniques acoustiques du CGPM participent au futur groupe de travail du CIEM sur le comportement des poissons et les méthodes acoustiques.

61. Le Secrétariat du CGPM a été prié de déterminer, avec l'aide du Secrétariat du CIEM, si cette participation était possible. Sinon, la Consultation a décidé que les activités acoustiques devraient être poursuivies au sein du CGPM. Si l'on décide d'organiser une autre consultation, M. Bencherifi a proposé de l'accueillir au Maroc.

62. La consultation a fait remarquer que, dans tous les cas, les questions concernant la recherche sur les méthodes acoustiques et les problèmes administratifs y relatifs, continueraient d'être étudiés au sein du CGPM, soit au cours de ses consultations sous-régionales sur l'évaluation des stocks, soit lors du Comité de l'aménagement des ressources, de ses sessions plénières ou en d'autres occasions.

63. La Consultation a également reconnu la nécessité d'une formation plus approfondie à tous les niveaux et recommandé que la FAO s'efforce de fournir des moyens supplémentaires dans ce domaine.

VIII. ADOPTION DU RAPPORT

64. Le rapport de la Consultation technique sur les méthodes acoustiques de détection et d'estimation de l'abondance du poisson a été adopté le 12 novembre 1982.

65. A la clôture de la session, les participants ont exprimé leurs chaleureux remerciements au pays hôte, au directeur de l'IEO et à son personnel ainsi qu'à MM. Brede et Borud pour la contribution précieuse qu'ils ont apportée à la Consultation.

APPENDIX A

Agenda

1. Opening of the Consultation

2. Adoption of the Agenda

3. Election of the Chairman

4. Summary of the ICES/FAO Symposium on Fishery Acoustics

5. Present situation of equipment and staff, and plans for acoustic surveys in Member States

6. Training and demonstration
   - 6.1 Simulator demonstration and exercises
   - 6.2 Video on use of standard sphere
   - 6.3 On board calibration exercise

7. Standardization
   - 7.1 Standard spheres
   - 7.2 Calibration on live fish

8. Review of stocks assessed acoustically
   - 8.1 Adriatic Sea
   - 8.2 Morocco/Spain
   - 8.3 Algeria/Tunisia
   - 8.4 Others

9. Future activities

10. Adoption of the Report

ANNEXE A

Ordre du Jour

1. Ouverture de la Consultation

2. Adoption de l'ordre du jour

3. Election du Président

4. Résumé du Symposium CIEM/FAO sur les méthodes acoustiques

5. Situation actuelle du matériel et du personnel, et plans de prospections acoustiques dans les Etats Membres

6. Formation et démonstrations
   - 6.1 Démonstration du simulateur et exercices
   - 6.2 Film sur bande magnétique sur la sphère normalisée
   - 6.3 Exercices d'étalonnage à bord

7. Normalisation
   - 7.1 Sphères normalisées
   - 7.2 Etalonnage sur du poisson vivant

8. Etude des stocks évalués par la méthode acoustique
   - 8.1 Adriatique
   - 8.2 Maroc/Espagne
   - 8.3 Algérie/Tunisie
   - 8.4 Autres

9. Activités futures

10. Adoption du rapport

APPENDIX B / ANNEXE B

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APPENDIX C

R/V DR. FRIDTJOF NANSEN : Determination of calibration constants

The calibration constant C, in particular the one used for the surveys in Tunisia and Algeria, was determined as described below.

A count of single fish (N_i) (cod in this case) is made and the area covered by the sample is determined (A_j).

The densities (ρ_i) thus obtained are plotted against the integrator readings (M_i).

$$\rho_j = \frac{N_i}{A_j}$$

The slope of the regression line is the constant C,

$$\rho = CM$$

This method is not very precise, due to the difficulty in correctly determining the area. This is done by reducing the recorder gain until all recordings just disappear, which means that the fishes are hardly recorded at the acoustic axis. The gain reduction (in dB) then tells how far from the axis fishes are recordable at the normal settings. The sample area is calculated from the corresponding angle in the directivity diagram for the transducer. This method, however, tends to over-estimate the sampling area when there are variations in the target strength.

The counts were actually made on the Norwegian research vessel JOHAN HJORT and converted for the research vessel FRIDTJOF NANSEN by inter-calibration in 1979. 1/ The C value for a cod-like fish of 40 cm total length thus determined was 10.5 t/n.mi^2/mm. This is made length dependent by dividing by 40 and multiplying by the average fish length in cm ($\frac{10.5}{40} \times L$).

The target strength TS is assumed to be proportional to 20 log L + A, since the scattering cross section $\sigma \sim L^2$ as shown by experiments with stunned single fish and $W \sim L^3$, $\frac{\sigma}{W} \sim L$.

The above C was determined for the 120 kHz echo-sounder on board research vessel FRIDTJOF NANSEN. Inter-calibration with the vessel's 38 kHz sounder gave $C_{38} = 0.2$ L.

The TVG board in the 38 kHz echo-sounder was changed in 1980 during a survey in Burma, resulting in a change in C, $C_{38} = 0.8$ L, which is the value used for the surveys in the Mediterranean and Western Africa.

This C value will be used until better estimates of TS by species become available.

The value of TS_{1kg} corresponding to the applied C value can be derived by the calculation:

$$TS_{1kg} = -10 \log C - SL - VR - G - 10 \log \frac{cr}{2} + 20 \log R_o + 2\alpha R_o - A + V_o$$

where C is expressed in kg/m^2.

SL + VR = 138 dB, based on calibration against a copper sphere of TS = -33.6 dB

$10 \log \Psi = -21.4$

$20 \log R_o + 2\alpha R_o = 64.5$ dB
(the gain at the end of the range for the time varied gain, R_o)

$TS_{1kg} = -10 \log L - 22$

1/ Before 1979, the C value was based on small pelagic fish of 17 cm.

Cage calibrations with the research vessel LEMURU on sardines of 5.2 cm average length gave TS_{1kg} = -28.4 dB, while the value from DR. FRIDTJOF NANSEN gives TS_{1kg} = -29.2 dB for the same fish length.

The surveys in Algeria and Tunisia

During the so-called judging, values of M are corrected for incorporation of plankton and bottom. An empirical scale was developed to measure plankton abundance.

If the ratio $\frac{EK\ 120}{EK\ 38}$ was high, there usually was much plankton.

The total biomass during the surveys was estimated as M x C x A, where A is the area of observed fish distribution within isolines of M. In Tunisia most of the fish classified as pelagic where actually easier to catch wtih a bottom trawl. In Algeria the long and narrow shelf posed a coverage problem. Rather big schools were found close to the coast, giving high integrator values. A big vessel is in such cases not always the most suitable tool to determine fish distribution. The data of the most recent surveys are available on floppy discs for further analysis.

ANNEXE C

NAVIRE DE RECHERCHE "DR. FRIDTJOF NANSEN": DETERMINATION DES CONSTANTES D'ETALONNAGE

La constante d'étalonnage C, en particulier celle qui a été utilisée pour les prospections en Tunisie et en Algérie, a été déterminée comme suit:

On compte les poissons isolés (N_i) (de morues en l'occurence) et l'on détermine la zone couverte par l'échantillon (A_j).

Les densités ($\int_i$) ainsi obtenues sont portées sur un graphique en regard des valeurs lues sur l'intégrateur (M_i).

$$\int_j = \frac{N_i}{A_j}$$

La pente de la droite de régression est la constante C.

$$\int = CM$$

Cette méthode n'est pas très précise en raison de la difficulté de déterminer correctement la zone en question. On la détermine en réduisant le gain de l'enregistreur jusqu'à ce que tous les enregistrements disparaissent, moment où les poissons présents sur l'axe acoustique ne laissent pratiquement plus de trace. La réduction du gain (en dB) indique alors à quelle distance de l'axe on peut enregistrer les poissons aux réglages normaux. La zone d'échantillonnage est calculée d'après l'angle correspondant dans le diagramme de directivité pour le transducteur. Toutefois, cette méthode tend à surestimer la zone d'échantillonnage lorsqu'il se produit des variations de l'indice de réflection de la cible.

Les calculs ont été effectués en fait à bord du navire de recherche norvégien "JOHAN HJORT" et convertis pourle navire de recherche "FRIDTJOF NANSEN" par inter-étalonnage en 1979 1/. La valeur C pour un poisson comme la morue de 40 cm de longueur totale ainsi déterminée était 10,5 $t/n.mi^2/mm$. On la rend dépendante de la longueur en la divisant par 40 et en la multipliant par la longueur moyenne du poisson en cm ($\frac{10,5}{40} \times L$).

L'indice de réflection de la cible est supposé être proportionnel à 20 log L + A, puisque la section diffusante est proportionnelle à L^2, comme le montrent les expériences avec des poissons isolés et "assommés" et que $W \sim L^3$, $\frac{\sigma}{W}$ est proportionnel à L.

La constante C ci-dessus a été déterminée pour l'écho-sondeur de 120 kHz à bord du navire de recherche "DR. FRIDTJOF NANSEN". L'inter étalonnage avec le sondeur 38 kHz du navire a donné $C_{38} = 0,2$ L.

Le GVT de l'écho-sondeur 38 kHz a été changé en 1980 au cours d'une prospection en Birmanie, ce qui a eu pour effet de changer C, $C_{38} = 0,8$ L qui est la valeur utilisée pour les prospections en Méditerranée et en Afrique de l'Ouest.

1/ Avant 1979, la valeur C était fondée sur le petit poisson pélagique de 17 cm.

Cette valeur de C sera utilisée jusqu'à ce que l'on obtienne de meilleures estimations de l'indice de réflexion par espèce.

La valeur de $TS_{1\ kg}$ correspondant à la valeur appliquée de C peut être dérivée par calcul:

$$TS_{1\ kg} = -10 \log C - SL - VR - G - 10 \log \frac{C\Psi}{2} + 20 \log R_o + 2\alpha R_o - A + V_o$$

dans laquelle C est exprimé en kg/m^2.

SL + VR = 138 dB, fondée sur l'étalonnage avec une sphère de cuivre de TS = -33,6 dB.

$10 \log \Psi = -21,4$

$20 \log R_o = 20\alpha(R_o = 64,5$ dB (gain à l'extrémité de la portée du GVT, R_o)

$TS_{1\ kg} = -10 \log L - 22$

L'étalonnage des cages sur le navire de recherche "LEMURU" pour les sardines de 5,2 cm de longueur moyenne ont donné $TS_{1\ kg}$ = -28,4 dB alors que la valeur obtenue par le "DR. FRIDTJOF NANSEN" donne $TS_{1\ kg}$ = -29,2 dB pour la même longueur du poisson.

Prospections en Algérie et en Tunisie

Lors de l'examen des enregistrements, les valeurs de M sont corrigées pour tenir compte du plancton et du fond. Un barème empirique a été mis au point pour mesurer l'abondance du plancton. Si le rapport $\frac{EK\ 120}{EK\ 38}$ est élevé, il indique généralement l'existence d'une grande quantité de plancton.

Pendant les prospections, la biomasse totale a été estimée comme suit: M x C x A, dans lequel A est la zone d'observation de la répartition du poisson entre les lignes isoplèthes de M. En Tunisie, la plupart des poissons classés parmi les espèces pélagiques ont été en fait plus faciles à capturer avec un chalut de fond. En Algérie, le plateau continental long et étroit pose un problème de couverture. On a trouvé des bancs de poisson assez importants près de la côte, ce qui a donné des valeurs de l'intégrateur élevées. Dans ces cas-là, un gros navire n'est pas toujours l'instrument le mieux adapté pour déterminer la répartition du poisson. Les données des prospections les plus récentes sont disponibles sur disquettes pour une étude plus approfondie.

APPENDIX D / ANNEXE D

SITUATION DE LA RECHERCHE ACOUSTIQUE A L'INSTITUT SCIENTIFIQUE ET TECHNIQUE DES PECHES MARITIMES (FRANCE) AU COURS DES TROIS DERNIERES ANNEES

par

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1. Campagnes "acoustiques" réalisées

Dates	Navires	Objet de la campagne - lieu
19 au 26.06.79	Thalassa	Etalonnage acoustique, calibration sur poissons vivants; Golfe de Gascogne
10 au 30.07.79	Thalassa	Evaluation du stock de hareng dans le secteur nord-Ecosse; programme coordonné par le CIEM.
26.02 au 4.04.80	Agulhas (Sud Afrique)	Evaluation du stock de krill de l'Antarctique. Embarquement de R. LE MEN comme observateur.
28.05 au 6.06.80	Thalassa	Etalonnage acoustique, calibration sur poissons vivants: Golfe de Gascogne.
11 au 31.07.80	Thalassa	Evaluation du stock de hareng dans le secteur nord -Ecosse: programme coordonné CIEM.

Janvier à février 81, indisponibilité de la "Thalassa" à la suite de l'incendie qui a détruit sa passerelle.

5 au 11.08.81	Thalassa	Etalonnage acoustique et essais du nouveau matériel de détection installé à bord.
12 au 26.08.81	Clione (Angleterre)	Essais techniques, mesures d'index de réflexion; côte est d'Angleterre. Embarquement de R. LE MEN
3 au 18.11.81	Thalassa	Evaluation du stock de hareng dans le secteur Manche est-sud Mer du Nord. Essais en parallèle des échointégrateurs SIMRAD QD et AGENOR.
12 au 30.03.82	Thalassa	Application de l'échointégration à la mesure de l'efficacité des chaluts: Golfe de Gascogne.
4 au 11.05.82	Thalassa	Essai de détermination de la densité des peuplements planctoniques par échointégration; Golfe de Gascogne.

2. Campagnes prévues pour fin 1982 et l'année 1983

8 au 22.10.82	Thalassa	Evaluation acoustique des poissons pélagiques sur les côtes d'Algérie 1/.
Nov. 82 à mars 83	Refonte du n/o Thalassa (augmentation de la puissance motrice, aménagement des installations de pêche, installation d'un loch Doppler...).	
19.04 au 4.05.83	Thalassa	Evaluation du stock d'anchois dans le golfe de Gascogne 2/.
14 au 28.11.83	Thalassa	Evaluation du stock de hareng en Manche est-sud mer du Nord.

3. Nouvel équipement acoustique du n/o "Thalassa"

A la suite de l'incendie qui a détruit sa passerelle, la totalité de l'appareillage acoustique de la "Thalassa" a dû être remplacé. On dispose maintenant à bord de:

- Un Sondeur vertical scientifique SIMRAD EK 400, bifréquence 38 et 120 kHz. En 38 kHz, le transducteur de coque est à double faisceau (9^o x 13^o et 22^o x 13^o) et il est possible d'utiliser un transducteur remorqué. En 120 kHz le transducteur est à faisceau conique simple (10^o).

- Un Sondeur scientifique SIMRAD ET 100, 49 kHz, utilisé principalement comme netsonde. Mais il comporte également un transducteur de coque (8^o x 11^o) et peut donc être utilisé comme sondeur vertical. Ce netsonde est équipé d'une paravane Simrad FR 500 permettant le sondage classique vers le haut ou vers le bas, l'indication de la température de l'eau, mais également, grâce à l'adjonction d'un capteur pression et d'une électronique spéciale, la reproduction de l'évolution du chalut en mouvement vrai sur l'enregistreur.

- Un Echointégrateur Digital à 10 voies, SIMRAD QD, comportant une interface QX avec les sondeurs. Cet appareil, qui est commandé par un terminal SILENT 743, peut être connecté aux 3 sondeurs (38, 49 ou 120 kHz) évoqués ci-dessus.

- Un Oscilloscope à mémoire HP 1741 A et un ensemble d'étalonnage.

- Un Sondeur vertical Atlas Tiefseelot 15 kHz pour le sondage profond.

- Un Netsonde sans câble FURUNO FNR 200.

4. Remarques sur l'utilisation du nouveau matériel SIMRAD

Incontestablement, le nouveau matériel SIMRAD sondeurs scientifiques EK 400 ou ET 100 et échointégrateur QD, possède de très grandes possibilités et une souplesse d'emploi que n'avaient pas les anciens appareils (sondeurs EKS et échointégrateur Qm).

Les principaux avantages que l'on peut en tirer pour l'utilisation en échointégration:

- **Sondeur**	TVG stable, meilleure discrimination de l'écho de fond par "Bottom window" et/ou "minimum depth"; Choix plus grand d'échelles, d'atténuation, puissance émise...
- **Echo-intégrateur**	Dynamique plus grande et donc peu de risques de saturation; choix possible de 10 couches; très grande souplesse d'utilisation

1/ Cette campagne est programmée dans le cadre d'une coopération franco-algérienne. C'est le gouvernement algérien qui sera le propriétaire des données, et qui, donc seul pourra éventuellement communiquer au CGPM les résultats de cette campagne.

2/ Il sera possible d'accueillir sur la "Thalassa", à l'occasion de cette campagne, des experts en acoustique en provenance des pays étrangers.

Mais ce matériel semble être très fragile et, après simplement un an d'utilisation (août 81 à août 1982), nous avons eu de nombreuses pannes à déplorer:

- **Sondeur** — Sensibilité à la chaleur ambiante (clavier de commande devenant inopérant); problème d'affichage des réglages sur l'unité de contrôle); problème de trigger et échelle 0-50 m impossible à obtenir); panne de la carte d'alimentation 5 V de l'EK 400.

- **Echo-intégrateur** — Panne et changement de la carte "high speed computer"; mauvais fonctionnement de l'imprimante SILENT.

Enfin, les manuels d'utilisation ne sont à notre avis pas suffisament explicatifs voire même incomplets et il est, par exemple, très difficile d'effectuer l'étalonnage électronique complet de l'EK 400 si l'on se contente de lire le manuel.

APPENDIX E / ANNEXE E

ESTIMATION ACOUSTIQUE DE LA BIOMASSE DES STOCKS PELAGIQUES AU MAROC: MATERIEL ET METHODES UTILISES; DIFFICULTES

par

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I. INTRODUCTION

L'importance socio-économique de l'existence d'un stock pélagique composé principalement de sardine au Maroc a conduit à la mise en place d'un programme de prospections acoustiques, dont le but est d'évaluer la biomasse des stocks pélagiques et de contrôler la distribution de leur abondance dans le temps et l'espace.

Ce programme est réalisé par l'Institut scientifique des pêches maritimes de Casablanca avec l'assistance de la FAO; le matériel acoustique utilisé est composé d'un sondeur associé à un échointégrateur, et d'un sonar.

Les données collectées au cours des campagnes acoustiques sont traitées au moyen d'un miniordinateur. Depuis 1979, douze campagnes d'évaluations et de calibrations ont été réalisées.

Une méthode qui consiste à combiner les données obtenues par le sondeur-intégrateur d'une part et le sonar d'autre part est utilisée pour l'évaluation de la biomasse du stock sardinier.

La description de cette méthode, effectuée par Bazigos et al, 1980 et Lamboeuf et al, 1982 n'est pas reprise ici. La présente note se limite à la description du matériel utilisé, des problèmes techniques et méthodologiques, ainsi que des solutions qui leur ont été apportées pour évaluer la biomasse du stock sardinier au Maroc.

II. MATERIEL UTILISE POUR L'EVALUATION

1. Matériel de prospection

Le matériel acoustique est installé à bord du N/O "IBN SINA", chalutier pêche arrière de 39 m, d'une puissance de 1 100 ch. Il est ainsi composé:

- Sondeur EKS 38 SIMRAD
- Sondeur EKS 120 SIMRAD
- Intégrateur QM.MK II SIMRAD avec un enregistreur à deux canaux HP 7702 B
- Sonar SK 3
- Ensemble de calibration
  - Générateur HP 204 C
  - Voltmètre à tube vide HP 400 F
  - Compteur de fréquence HP 5381 A
- Oscilloscope HP 1741 A

2. Matériel acoustique pour la pêche

- Sondeur EQ 38 SIMRAD
- Netsonde FB3 SIMRAD
- Trawl watch FH SIMRAD
- Indicateur digital de profondeur FI SIMRAD

3. Equipement acoustique à terre

Au laboratoire, un équipement acoustique complet est disponible, soit pour être monté à bord d'un autre navire, soit pour des démonstrations dans le cadre des cours de formation de professionnels ou de scientifiques.

- Sondeur EK 38 A SIMRAD
- Intégrateur QM.MK II avec un enregistreur à double canal HP 7702 B
- Oscilloscope HP 141 A
- Générateur de signaux, voltmètre, atténuateur, compteur de fréquence.

4. Matériel de traitement

Un mini-ordinateur HP 9845 B est utilisé pour le traitemnet des données collectées lors des campagnes acoustiques.

M. Coppola, consultant programmeur de la FAO a mis au point un jeu de programmes d'entrée, traitement, tabulation et présentation des données du sonar et de l'intégrateur.

Au total 24 programmes en Basic pour le mini-ordinateur sont disponibles.

Nom des programmes	Intégrateur	Sonar
Départ: sélection entre les jeux de programmes du sonar et de l'intégrateur	X	X
Paramètres: Chargement des paramètres du système	X	X
Contrôle: sélection des programmes	X	X
Saisie: saisie des données	X	X
Edition: sur l'écran pour vérification	X	X
Recherche d'erreurs: dépistage des erreurs logiques	X	X
Edition: sur papier	X	X
Corrections: insertion des corrections	X	X
Tri: tri des fichiers en ordre logique	X	X
Stratification: entrée des limites de stratification bathymétriques et géographiques	X	X
Transfert: transfert des paramètres communs du fichier intégrateur au fichier sonar	-	X
Calculs statistiques: calculs par strate des indices de biomasse, de leur variance, et de la biomasse	X	-
Distribution verticale: graphique de répartition de la biomasse détectée au sondeur	X	-
Distribution des bancs: graphique de répartition horizontale des bancs détectés au sonar	-	X
Tabulation: établissement des tableaux de biomasse, index de biomasse, indice de densité, biomasse absolue, densité absolue, probabilité de détection.	X	-

III. CAMPAGNES ACOUSTIQUES EFFECTUEES

- Mai 1979:
  Campagne de distribution et évaluation de la biomasse de sardine dans l'Atlantique entre Safi (32°30 N) et Dakhla (24° N); seules les données sondeur-échointégrateur sont disponibles.

- Novembre 1979:
  Campagne de distribution et d'évaluation de la biomasse de sardine en Atlantique; région couverte Agadir-Cap Blanc; sondeur + sonar.

- Février 1980:
  Campagne de calibration avec bécasses de mer vivantes (Macrorhamphosus scolopax et M. gracilis).

- Avril 1980:
  Campagne de calibration avec sardines vivantes, (Sardina pilchardus).

- Juillet 1980:
  Campagne de distribution et d'évaluation de la biomasse des petits pélagiques dans la région du COPACE (Comité des pêches pour l'Atlantique Centre-Est). Campagne conjointe avec les N/O "CORNIDE DE SAAVEDRA" et "CAPRICORNE". Zone couverte par le N/O "IBN SINA": Safi-Cap Timiris (Mauritanie); sondeur + sonar.

- Novembre 1980:
  Campagne de distribution et d'évaluation de la biomasse en Atlantique, de Safi à cap Barbas; sondeur + sonar.

- Février 1981:
  Campagne de méthodologie: expériences pour l'estimation du poids moyen d'un banc, et pour l'étude du comportement de la sardine; phénomène d'évitement, migrations.

- Octobre 1981:
  Campagne de distribution et d'évaluation de la biomasse en Atlantique, de Safi à cap Barbas; sondeur + sonar.

- Février 1982:
  Campagne de distribution et d'évaluation de la biomasse de sardine en Atlantique; région Jorf Lasfar-cap Barbas; sondeur + sonar.

- Mai 1982:
  Campagne de distribution et d'évaluation de la biomasse des petits pélagiques: sardine, anchois, bécasse de mer, etc. dans les eaux marocaines atlantiques du cap Ghir au cap Spartel et méditerranéennes du cap Spartel à Saidia; sondeur + sonar.

- Juin 1982:
  Prospection pilote dans la zone d'opération de la flottille marocaine pour guider les pêcheurs vers les concentrations de sardines.

- Octobre 1982:
  Campagne de distribution et d'évaluation de la biomasse des petits pélagiques dans la région Casablanca-cap Barbas; sondeur + sonar.

IV. PROBLEMES RENCONTRES ET SOLUTIONS ADOPTEES POUR L'EVALUATION DU STOCK SARDINIER

Ces problèmes sont de deux sortes: tout d'abord ceux d'ordre technique liés aux mesures des performances du système acoustique et au très fort pouvoir réflecteur des bancs de sardines; ensuite ceux d'ordre méthodologique liés en grande partie au comportement de l'espèce et au traitement des données.

1. Problèmes techiques

1.1 Mesure des performances du système acoustique et constante d'étalonnage

Des difficultés ont été rencontrées lors des mesures des performances du matériel acoustique au moyen de l'hydrophone. Elles sont liées à la difficulté de positionner l'appareil dans l'axe acoustique du transducteur et à l'instabilité de ses performances qui changent avec le temps et la température de l'eau (Elminowics et al., 1982).

Une deuxième méthode de mesure des performances acoustiques du sondeur a ensuite été utilisée. Elle consiste à mesurer l'intensité de l'écho réfléchi par une sphère métallique de propriété acoustiques connues. Nous avons eu l'occasion d'utiliser deux types de sphères:

- Sphère de cuivre de diamètre 60 mm et TS = 33,57 dB
- Sphère de carbure de tungstène de diamètre 38,1 mm et TS = 42,3 dB

Le positionnement de la sphère et les mesures obtenues sont beaucoup plus stables qu'avec l'hydrophone. On notera cependant que la sphère de carbure de tungstène, au moins en ce qui nous concerne, est plus pratique, car son pouvoir réflecteur étant plus faible, les mesures peuvent être effectuées à une distance du transducteur plus courte qu'avec la sphère de cuivre. Cette dernière provoque en effet une saturation du sondeur pour des distances inférieures à 10 mètres et il n'existe pas sur la côte marocaine atlantique de sites abrités dépourvus de courants, et présentant des profondeurs supérieures à 10 mètres.

L'alignement des sphères sur l'axe acoustique du transducteur est réalisé au moyen de trois petits treuils à main, et d'un système de renvoi de cables permettant leur manipulation par un seul opérateur qui peut en même temps surveiller l'écho de la sphère sur l'oscilloscope.

1.2 Performances des transducteurs magnétostrictifs

On a remarqué que leurs performances se détradaient avec le temps; ainsi après trois à quatre années, ils ne sont plus utilisables pour des mesures quantitatives. Ce phénomène est, semble-t-il, dû à une attaque bactérienne de l'isolant du bobinage, cette attaque étant plus rapide dans les eaux chaudes. Les transducteurs céramiques ne présentent pas cet inconvénient.

1.3 Pouvoir réflecteur des bancs

Les bancs de sardines ont un pouvoir réflecteur très élevé et souvent égal ou supérieur à celui du fond. Le système d'élimination des échos de fond utilisés dans l'échointégrateur analogique SIMRAD MK II, repose sur l'amplitude des signaux. Il arrive donc souvent que des bancs denses de sardines soient pris pour le fond et ainsi exclus de l'intégration.

Pour remédier à cet inconvénient, un circuit complémentaire a été mis au point par M. E.J. Simmonds, et installé sur notre échointégrateur. D'une manière très simple, ce circuit n'autorise un écho à être considéré comme étant dû au fond, que s'il apparaît dans une "fenêtre" variable de 1,50 à 3 m de part et d'autre de l'écho de fond enregistré pendant la transmission précédente. Ce circuit a permis de faciliter le travail de validation des données de densité fournies par l'échointégrateur, notamment dans les situations où la sardine se présente sous forme de bancs denses proches du fond.

2. Problèmes méthodologiques

Ces problèmes sont liés au comportement de la sardine qui, distribuée près de la surface, n'est pas accessible en totalité au sondeur vertical.

2.1 Le sondeur intégrateur

La disponibilité de la sardine au sondeur intégrateur est limitée. L'analyse de sa distribution verticale indique qu'une partie des concentrations est située près de la surface, dans une zone que le sondeur vertical ne couvre que partiellement ou pas du tout. Ce phénomène est accentué par les réactions de fuite des bancs à l'approche du bateau. Pour remédier à cet inconvénient, on utilise le sonar pour couvrir la tranche superficielle ignorée ou biaisée par le sondeur. Le sonar dirigé horizontalement selon un angle de 90° avec le cap du navire permet de compter le nombre de bancs de poissons situés sur les côtés du bateau.

2.2 Le sonar

Le sonar en tant que moyen d'échantillonnage présente lui aussi des inconvénients en raison de son efficacité limitée: il est dépourvu de TVG et seuls les bancs proches et/ou denses sont enregistrés. Son faisceau s'incurve vers le bas en raison des gradients thermiques négatifs de la surface vers le fond. Le volume échantillonné est irrégulier; son épaisseur croit au fur et à mesure que l'on s'éloigne du bateau.

Pour tenir compte de ces inconvénients, on a été amené à déterminer une zone dite "bande efficace" dans laquelle on considère que le nombre de bancs enregistrés est entaché d'un minimum d'erreurs.

2.3 Estimation de la biomasse

Pour tenir compte des particularités de la distribution verticale des sardines et minimiser les biais que cette situation engendre, une méthode particulière d'évaluation de la biomasse a été mise au point. Elle consiste à combiner les estimations obtenues à partir du sondeur vertical avec celles obtenues par le sonar. Les données obtenues par le sonar sont représentatives de la partie superficielle et de celles, obtenues par le sondeur, de la partie sous-jacente.

L'estimation de la biomasse à partir des données du sondeur-intégrateur est obtenue par la méthode classique utilisant le coefficient d'étalonnage des appareils et les mesures de densité des concentrations de poissons.

La méthode d'estimation de la biomasse détectée au sonar est dérivée de celle de Smith (1970); elle fait appel au comptage du nombre de bancs par unité de surface multiplié par le poids moyen d'un banc.

2.4 Détermination du poids moyen d'un banc

Quelques difficultés ont été rencontrées et plusieurs approches ont été essayées:

- Analyse des captures. Les données des débarquements de la flottille de pêche commerciale ne concernent qu'une partie de l'aire de distribution du stock sardinier. Si l'on considère que l'effort de pêche dans cette région est tel que la presque totalité des bancs présents soit capturée, la moyenne des tonnages par coup de senne constitue une bonne estimation du poids moyen des bancs. Ce chiffre ne peut cependant pas être appliqué à la totalité de l'aire de répartition. On constate en effet de grandes différences dans la taille des bancs en comparant les détections obtenues avec celles d'autres régions.

- Comparaison dans une région déterminée entre le nombre de bancs détectés pendant le jour et la biomasse calculée avec les données du sondeur-intégrateur pendant la nuit. L'expérience n'a pas conduit au résultat souhaité en raison de la migration du poisson hors de la zone et de la distribution hétérogène dans la région considérée.

- Des mesures des dimensions des bancs sur les échogrammes ont été effectuées pour déterminer leur volume. En admettant que ces mensurations, bien qu'imprécises soient utilisables, on ne dispose pas de moyens de déterminer la densité pondérale à l'intérieur des bancs.

- Le comptage du nombre d'impulsions par banc permet d'obtenir une bonne estimation de leur largeur, connaissant la distance parcourue par le bateau entre deux impulsions. Ce comptage, s'il est effectué sur le papier de l'intégrateur, conduit à une surestimation de la taille moyenne des bancs car seuls les bancs de forte densité donnent une déflection observable. L'utilisation d'un compteur d'impulsions devrait permettre d'obtenir des résultats plus représentatifs.

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APPENDIX F / ANNEXE F

SITUACION ACTUAL DEL EQUIPO Y PERSONAL, Y PLANOS PARA RECONOCIMIENTOS ACUSTICOS EN ESPAÑA

A. BARCOS CON EQUIPO ACUSTICO

Barco CORNIDE DE SAAVEDRA (1000 tons, 60 m)

- Ecosondador EK 400-38 Simrad
- Ecosondador EK 400-120 Simrad
- Integrador Digital QD - Terminal Texas Silent
- Ecosondador Simrad EK 38 (papel humedo)
- Integrador Analógico Simrad QM-MK II
- Magnetofono Tandberg
- Unidad de calibración
- Osciloscopio HP
- Sonar Elac

Barco ODON DE BUEN (70 tons, 23 m)

- Econsondador Simrad EK 38 S
- Ecosondador Simrad EK 120 S
- Integrador analógico QM MK II
- Unidad de calibración
- Osciloscopio HP
- Corredera Simrad NL

Barco GAVINA II (10 m)

- Ecosondador Simrad EY-M 50 kHz
- Magnetofono cassette Seoum SC - 1007
  (este equipo es portatil)

B. MATERIAL DE CALIBRACION: HIDROFONOS B-K Y LC 38, ARO DE CALIBRACION, ESFERAS DE COBRE SIMRAD PARA 38 Y 120, JAULAS DE CALIBRACION, VIVEROS PARA PECES, ETC.

Personal

- 2 Biólogos especialistas en técnicas de evaluación acústica
- 4 Biólogos iniciados en técnicas de evaluación acústica
- 1 Ingeniero técnico electrónico
- 6 Instrumentistas

c. PLANES DE CAMPAÑA PARA 1983

- Campaña de evaluación acústica stocks pelágicos mediterraneo peninsular español (CORNIDE DE SAAVEDRA);
- Campaña de evaluación acústica stocks pelágicos islas Baleares (ODON DE BUEN);
- Campañas acústicas bimensuales sur de Mallorca seguimiento stock pelagico explotado (ODON DE BUEN);
- Campaña evaluación sardina Galicia (CORNIDE DE SAAVEDRA);
- Campaña evaluación anchoa cantabrico (CORNIDE DE SAAVEDRA)

Esta programación para 1983 esta todavia pendiente de aprobación por la dirección del I.E.O.

APPENDIX G / ANNEXE G

A REVIEW OF THE STATUS OF ACOUSTIC RESEARCH IN ITALY AVAILABLE: FACILITIES AND EQUIPMENT

EQUIPMENT USED IN THE CALIBRATION AND ECHOSURVEY

1. Fish-finding instruments and calibration equipment

Echosounder EK 38 Recorder 11000 Magnifier	SIMRAD
Sonar SL Video Sonar QL	SIMRAD
Calibration equipment	Hewlett-Packard/Wavetak)
2 calibrated hydrophones	(Brüel and Kjaer)
Oscilloscope 1741A	(Hewlett-Packard)

Note The echosounder and sonar are outdated. Next year a new echosounder EK 400, in the double frequency version (38 kHz/120 kHz), will be purchased.

2. Echo processing instruments

Analog echointegrator QM Display converter Digital echointegrator QD	SIMRAD

The above instruments are part of a system based on the H.P. minicomputer 9825

The system includes:

- a scanner (3495 H.P.)
- a printer (9871 H.P.)
- a mass memory (1 M byte)
- different types of interfaces, etc.

This equipment has been described in Azzali (1981): The use of an on-line minicomputer for hydroacoustical echo-signal processing. In Meeting on hydroacoustical methods for the estimation of marine fish population, 25-29 June, 1979, Vol.2, Part a, edited by J.B. Suomala, Cambridge, Massachusets, Charles Stack, Draper Laboratory, Inc., pp. 439-54.

3. Instruments to measure the spead/position of the vessel

Doppler effect log	(Dolog 10 ATLAS KRUPP)
Gyzo	(Microtecnica)
Satellite system + Display	(Magnavox MX 1105)
Loran C + Plotter	(Decca)

4. Instruments to measure atmospheric data

The atmospheric data that are measured regularly during the acoustic survey through the system described in 2 are:

- Air temperature
- Air pressure
- Humidity
- Speed/direction of wind

} sensors from S.I.A.P.

5. Other data acquired during the acoustic survey

- Water temperature (at surface)
- Pitch and Roll
- R.P.M. (revolution per minute of the motor axis, correlated with the Vessel noise)

6. Instruments used during the biological stations

Netsonde with cable (ELAC)
Echo sounder (ELAC)

} They use the same frequency (33 kHz) and have the same type of recorder

7. Instrument used during the oceanographic stations

C.T.D. + Deck unit + Taperecorder (MARK II of Neil Brown)

II. DIFFICULTIES ENCOUNTERED AND PLANS TO OVERCOME THEM

In the last three years the northern and middle Adriatic sea, from the Italian coast to the mid-line has been surveyed regularly. The biomass, distribution and behaviour (diurnal migration, size of schools and their structure, etc.) of the Sardine/Anchovy/Sprat stocks have been estimated using the computer facilities.

The difficulties encountered during the survey and the data processing are:

- Vessel noise: It is too high (-25-30 dB) so that cleaning data is often a long and difficult work.

- Echosounder performances: The EK 38 is out of date, its peformances (especially the TVG function) are often unaccurate, so that the echosurvey data must be corrected. This is a difficult operation.

- The lack of data from the mid-line to the Yugoslav coast: Till now, we have not been able to cover the entire area of distribution of the stocks. It has been attempted to extrapolate the data from the mid-line to the Yugoslav coast; but this is not a very accurate operation.

About the first two problems, it has been decided to purchase the new echosounder EK400, at the beginning of 1983. The EK 400 can work with double frequency (38 kHz and 120 kHz); the noise of the vessel should be drastically reduced at 120 kHz.

The problem of lack of information on the Yugoslav area can be solved, approximately, if the data of relative abuncance collected by the Yugoslav vessel "Bios" can be utilized. This is possible through an electrical intercalibaration of the Yugoslav and the Italian vessels. It is planned to carry

out this intercalibration before the third consultation on stock assessment in the Adriatic (Fano, June 1983). The method of intercalibration based on the standard sphere seems the most suitable for this particular case. However, at present, neither the Italian nor the Yugoslav laboratory has a standard target.

III. PROGRAMME FOR 1983

The first months of 1983 will be spent on:

- the installation of the new instruments on the vessel, to fit the processing system to the new instruments, and to check them;

- to carry out the intercalibration with the Yugoslav vessel.

Two surveys are planned in the second part of 1983; the first to be carried out in June, the second in September.

Before each acoustic survey, the calibration constant will be determined with the Direct Method (live fish calibration).

APPENDIX H / ANNEXE H

SIMRAD
Marine

Checking of TVG-functions by means of the Simrad QD Digital Echo Integrator.

The Simrad QD provides an excellent way of checking the EK400 receiver TVG-function.

The procedure is as follows:

1. Remove diode D3 on the Transceiver Interface Board (circuit diagram 055131.7) in the transceiver unit.
   This enables triggering of the QD with EK400 in test mode.

2. Set the EK400 to transducer position 5 (Test Low) and stop the Recorder by means of the internal ON/OFF switch.

3. Measure the signal voltage at the calibrated output corresponding to the TVG-function to be checked. When checking the 40 log R-function the signal connection to the QD must be changed to the 40 log R-signal.
   (Transceiver connector J303 pin 8 or 30 depending on transceiver used.)
   The signal level should be approx. +10 dB//1 V rms.

   Note the exact signal level, $U_{cal.}$ and start the recorder.

4. Set up the QD depth layers according to table 1, 2, 3 or 4 depending on frequency and TVG.

5. Input to the QD LO 10 and PD.2 and Yes for normalizing to 1 nm. Then input Start and the QD will begin to integrate the signal in the different depth layers.
   Note values in the appropriate table.

6. If the above measured U_{cal} is not exactly +10 dB//1 V the mm deflection pr nm measured by the QD must be corrected before comparing the results with the theoretical values in tables 1 to 4.

   Example of correction:
   Measured U_{cal} = +10,7 dB//1 V rms. Difference from +10 dB = 0,7 dB. Correction to measured values will then be –0,7 dB. The logarithm to the correction factor is:
   $\frac{-0,7}{10} = -0,07.$
   Correction factor: $C = 10^{-0,07} = \underline{0,851}.$

   Multiply all mm deflections with C and compare with correct values.

   Deviation in dB from correct value is:

$$D = 10 \log \frac{mm_{measured}}{mm_{correct}}$$

SIMRAD

Table 1

EK400 38 kHz 20 log R TVG-check.

U_{cal} = dB//1 V C = dB

No.	Layer (m)	Measured Deflection (mm)	Corrected Deflection (mm)	Theoretical Deflection (mm)	D Deviation (dB)
1	15– 30			.046	
2	30– 60			.403	
3	60–100			1.90	
4	100–200			22.7	
5	200–300			87.8	
6	300–400			245	
7	400–500			583	
8	500–581			941	

Table 2

EK400 38 kHz 40 log R TVG-check.

U_{cal} = dB//1 V C = dB

No.	Layer (m)	Measured Deflection (mm)	Corrected Deflection (mm)	Theoretical Deflection (mm)	D Deviation (dB)
1	25– 50			.130	
2	50–100			4.87	
3	100–140			25.5	
4	140–180			90.8	
5	180–200			97.3	
6	200–220			156	
7	220–230			108	
8	230–242			164	

SIMRAD

Table 3

EK400 120 kHz 20 log R TVG-check.

U_{cal} = dB//1 V C = dB

No.	Layer (m)	Measured Deflection (mm)	Corrected Deflection (mm)	Theoretical Deflection (mm)	D Deviation (dB)
1	5– 15			.262	
2	15– 25			1.16	
3	25– 40			5.67	
4	40– 60			24.1	
5	60– 80			65.2	
6	80– 90			60.6	
7	90–100			89.5	
8	100–110			129.4	

Table 4

EK400 120 kHz 40 log R TVG-check.

U_{cal} = dB//1 V C = dB

No.	Layer (m)	Measured Deflection (mm)	Corrected Deflection (mm)	Theoretical Deflection (mm)	D Deviation (dB)
1	15– 30			.133	
2	30– 50			2.19	
3	50– 60			4.35	
4	60– 70			9.98	
5	70– 80			20.9	
6	80– 90			40.6	
7	90–100			74.9	
8	100–108			99.6	

APPENDIX I / ANNEXE I

CALIBRATION OF HYDROACOUSTIC EQUIPMENT USED TO EVALUATE FISH BIOMASSES BY USING ELASTIC AND SOLID SPHERES

by

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I. INTRODUCTION

This paper was written as an introduction to the discussion on problem of calibration of acoustic equipment used to evaluate the biomass of fish during the GFCM Technical Consultation on Acoustic Methods for Fish Detection and Abundance Estimation.

The subject has been widely discussed recently, for instance at the meeting of the Study Group on Acoustic Techniques that took place in Nantes in May 1981 or more recently at the Symposium on Fisheries Acoustics in Bergen in June 1982.

In the paper we shall just point out the theory on which the method of calibration of acoustic equipment, by using solid and elastic copper sphere, is based. We shall also describe its practical development and comment on some concrete and practical aspects that we consider as particularly interesting.

II. THEORY

We shall start from the basic equation of the sonar cited from different authors, inter alia by Urick (1967), Bodholt and Brede (1979) or Forbes and Nakken (1974).

The intensity of the echo received from the echo-sounder (see fig. 1) is obtained by the sonar equation :

$$EL = SL + TS - 2TL \qquad (1)$$

where

EL is the intensity of the echo received
SL is the measure of the effective power of a sound source
TS is the reflexion strength of the target which creates the echo
TL is the decrese of the intensity of sound caused by geometric diffusion and the transmission anomaly.

The transmission anomalies are conditioned by the absorption and dispersion of sound in water and by the refraction of the bordering surfaces and depends on the coefficient of absorption of sound in water (α).

Therefore:

$$TL = 20 \log R + \alpha R \qquad (2)$$

where

R is the maximum range of the TVG function.

Furthermore, if we also take into account that:

$$EL = V - VR \qquad (3)$$

where:

V is the voltage registered by the receiver when it records the echo.
VR is the entry voltage response.

Substituting (2) and (3) in (1) we have:

$$SL + VR = -TS + V + 40 \log R + 2\alpha R \qquad (4)$$

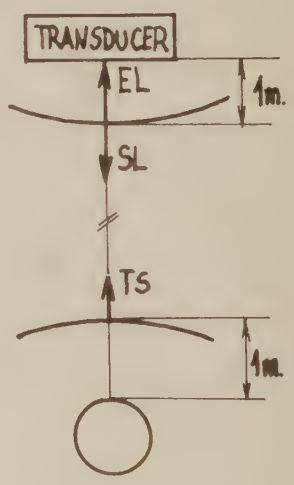

Figure 1. Components of Echolevel

so that the performance of the acoustic equipment (SL + VR) can be determined by placing a target of a known taarget strength TS in the acoustic axis of the transducer and measuring the voltage registered from the echo of the target (V). It is necessary to have a precise estimation of the attenuation coefficient of sound in water.

The TS of a target, which depends on size and other characteristics, is given by the relation (see fig. 2)

$$TS = 10\log \frac{I_r}{I_i} \qquad (5)$$

The reflexion strength of the target can be also expressed by another quantity, called the effective target area or scattering cross-section (σ) which is defined as follows: "If an echo were reflected by a total reflecting target with uniform spherical reflectivity pattern, the area of this target normal to the incident sound would be equal to σ".

TS and σ are related as follows:

$$TS = 10\log \frac{\sigma}{4\pi} \qquad (6)$$

But if we use a sphere as a target:

$$\sigma \sim \pi r^2 \qquad (7)$$

and sustituting in (6):

$$TS \sim 10\log \frac{r^2}{4} \qquad (8)$$

From this we see that the TS is a function of the radius of a shpere (see Bodholt and Brede, 1979, page 20).

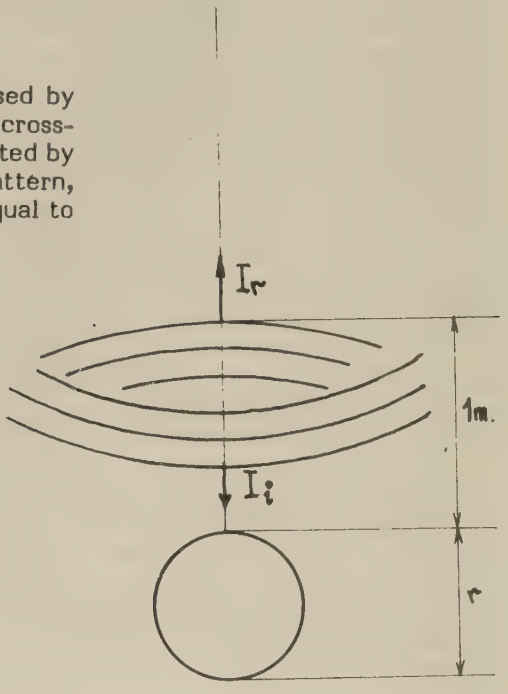

Figure 2. Incident and Reflected Intensity

III. TS OF THE CALIBRATION SPHERE

In practice when we try to establish the TS of the sphere used as reference target we find that the values obtained using expression (8) do not correspond to the values obtained experimentaly.

The subject has been studied by Foote, et al. (1981) and by Foote (1982). Spheres of identical sizes but built with different materials give different TS values. On the other hand the same sphere does not give identical values if the acoustic equipment works at different frequencies of emission.

It is obvious that different materials respond differently to working frequencies and that environmental conditions also affect the response.

They must therefore be taken into account when we determine the TS of a sphere. Nowadays standard spheres are being used whose TS has been determined a priori. Two of the most common frequencies used in acoustic equipment to evaluate fish biomasses are 38 kHz and 120 kHz. The TS values measured using electrical - grade copper spheres to calibrate the equipment of 38 kHz and 120 kHz are the following:

Frequency	Diameter	Measured TS
38 kHz	60.00 mm	-33.7 dB
120 kHz	30.05 mm	-37.0 dB

In any case the experimental determination of the TS of a sphere can be done by placing the sphere in the acoustic axis of a transducer and placing a multidirectional hdyrophone between the transducer and the sphere (see fig. 3). If the hydrophone is placed at 1 meter from the sphere and is connected to an oscilloscope, we can measure the incident energy and the reflected echo at one meter from the target.

It can be said, on the basis of the expression that defines the TS of a target, that:

$$TS = 20 \log \frac{V_i}{V_r} + 20 \log \frac{R_1}{R_1 + 1} \qquad (9)$$

We must realize that by using the measures V_i and V_r from the oscilloscope we will be working with relative measures of the sound energy; therefore hydrophone response and the environment conditions will not affect the results.

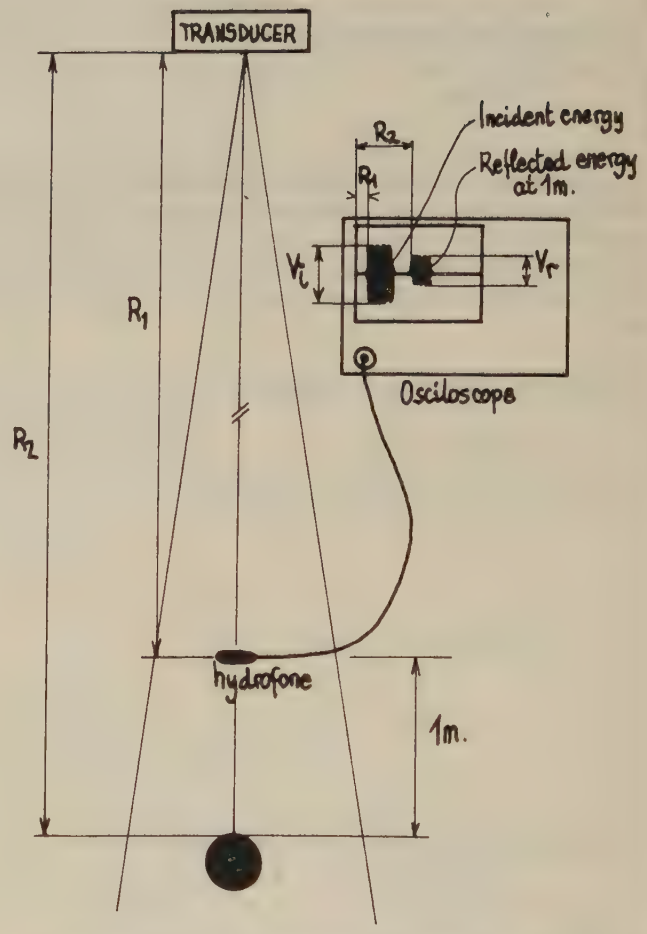

Figure 3. Experimental determination of the TS of a sphere

IV. DETERMINATION AND USE OF THE ABSORPTION COEFFICIENT

The absorption coefficient of sound in water (α) can be a source of errors to be taken into account in a survey of evaluation of biomasses by acoustic methods.

Foote (1981) points out that the influence of α in the determination of biomasses may be important. Its estimation can vary considerably according to the calculation method used. The author recommends the use of the Fisher and Simmons expression (1977) to estimate the α value, given that other expressions may introduce wrong values. Essentially the Fisher and Simmons expressions is the following (from Foote, 1981):

$$\alpha = A_1 f_1 f^2 / (f_1^2 + f^2) + A_2 P_2 f_2 f^2 / (f_2^2 + f^2) + A_3 P_3 f^2 \text{ nepers/m} \qquad (10)$$

Where:

$$A_1 = (1.03 \times 10^{-8} + 2.36 \times 10^{-10} T - 5.22 \times 10^{-12} T^2) \text{ sec/m}$$

$$f_1 = 1.32 \times 10^3 (T+273.1) \exp(-1700/(T+273.1)) \text{ Hz}$$

$$A_2 = (5.62 \times 10^{-8} + 7.52 \times 10^{-10} T) S/35 \text{ sec/m}$$

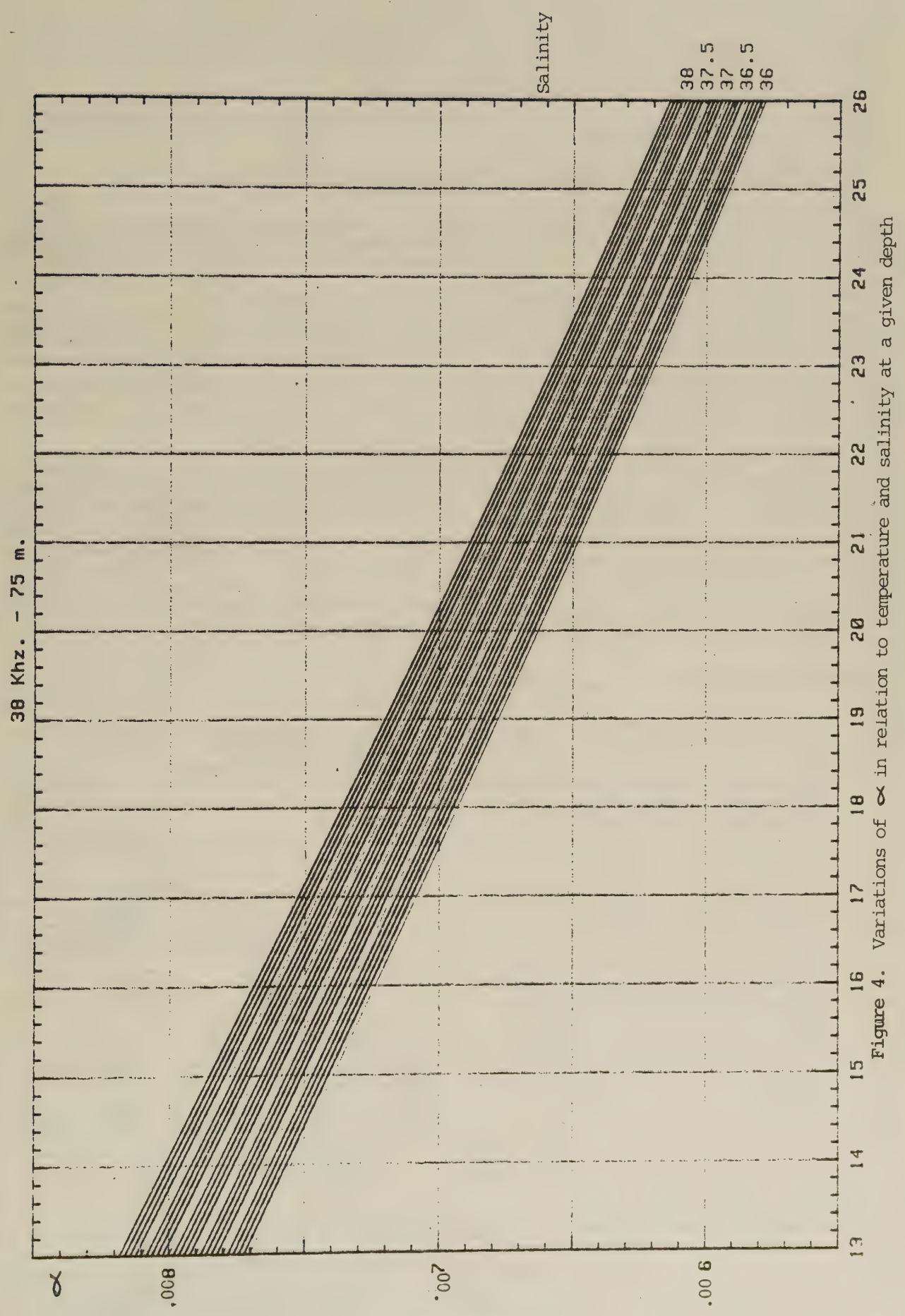

Figure 4. Variations of α in relation to temperature and salinity at a given depth

$f_2 = 1.55 \times 10^7 (T=273.1) \exp(-3052/(T+273.1))$ Hz

$P_2 = 1 - 1.03 \times 10^{-3} p + 3.7 \times 10^{-7} p^2$

$A_3 = (55.9 - 2.37T + 4.77 \times 10^{-2} T^2 - 3.48 \times 10^{-4} T^3) \times 10^{-5}$ sec^2/m

$P_3 = 1 - 3.84 \times 10^{-4} p + 7.57 \times 10^{-8} p^2$

f is the frequency in Hz, T temperature in °C, S salinity in ppm and p pressure in atm.

Starting from this conclusion we have selected the normal salinity and temperature in the western Mediterranean in the layer extending from the surface to 200 meters of depth (salinity 36-38 ppm and temperature 13-26 °C).

Using the Fisher and Simmons expression we calculate the corresponding α values according to each frequency. We have also used the α values given by SIMRAD in its calibration manual of the echosounder EK400 (0.008 dB/m for 38 kHz and 0.036 dB/m for 120 kHz).

The computer programme for the HP-9845, "F&C (H)" (see report, paragraph 29), draws the graphics with the curves of transmission loss (TL) at different depths and using different values of salinity, temperature and frequency.

In figure 6 we see that the loss curve of sound transmission (TL) related to the depth obtained by the α values given by SIMRAD does not always fit to the ones obtained with the salinity and temperature values chosen for the Mediterranean. For the selected ranges of salinity and temperature the curves obtained are similar. All this makes us believe that fixed salinity and temperature values can be established for every acoustic assessment survey done in the Mediterranean. Consequently a programme with the Fisher and Simmons' expression has been written in BASIC language for a computer HP-9845 B equipped with a plotter HP-9872 B (see report, paragraph 29). With this programme we can analyse the variation of the absorption coefficient (α) at different depths for different salinity values and for a chosen range of temperatures as shown in figure 4.

V. PRACTICAL PROCESS OF CALIBRATION

To make the calibration (performance calculation, SL+VR) of hydroacoustic equipment using as a reference a sphere of known TS, we follow this process (see figure 5).

1. We place a sphere in the acoustic axis of the transducer looking for the maximum signal registered in the oscilloscope.

2. We make the voltage reading corresponding to the sphere and we calculate the V_{rms} in dB.

3. We enter the obtained values in the expression (4). If the test is done with the TVG function in 40 logR position the values of R is the maximum range of the function (242 m for 38 kHz and 108 m for 120 kHz) using the following expression:

$$SL + VR = V_{rms} - TS + 40 \log R + 2\alpha R \qquad (11)$$

. If the position is 20 logR the value of R will be 581 meters for 38 kHz and 110 meters for 120 kHz, using the following expression:

$$SL + VR = V_{rms} - TS + 20 \log R + 2\alpha R + 20 \log R \qquad (12)$$

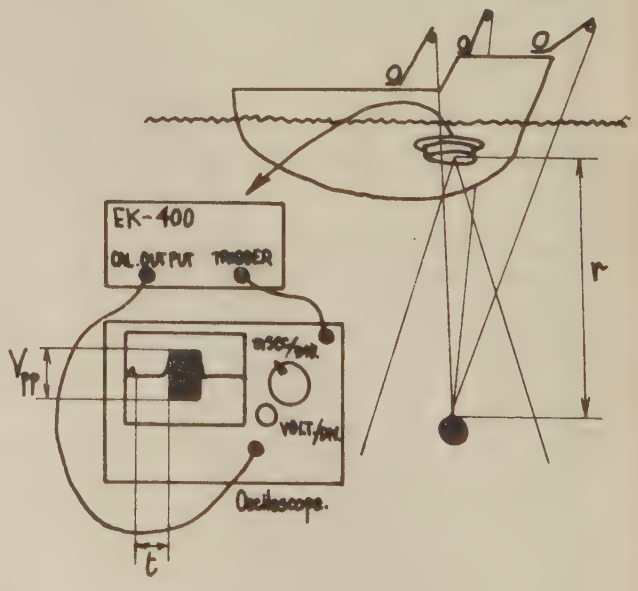

Figure 5. Calibration with standard spheres; determination of SL + VR

In this case it is necessary to introduce the corresponding correction to the transmission loss on the echo return.

The value of r to introduce in (12) is calculated through measurements on the oscilloscope, using the expression

$$r = \frac{txc}{2} \qquad (13)$$

where c is the sound velocity in water and t the time required for the sound to travel to and from the target measured in milliseconds (ms) (see. Fig. 6)

The echolevel U of the target is also measured on the oscilloscope as a V_{p-p} voltage (see fig.6 and 7). The V_{p-p} is converted into V_{rms} in decibel as follows:

$$20 \log V_{rms} = 20 \log \frac{V_{p-p}}{2\sqrt{2}} \qquad (14)\ 1/$$

The minimum depth at which the standard target should be placed may be calculated by using the expression:

$$r = 10^{\frac{(S + M + 10 \log P + TS + 17.8 - U)}{40}} \qquad (15)$$

r in meters
S and M are given transducer data
P = transmitter output power
U = maximum input signed to receiver (- 15 dB/1 volt in the EK400 and -35 dB/1 Volt in the EK-S sounder).

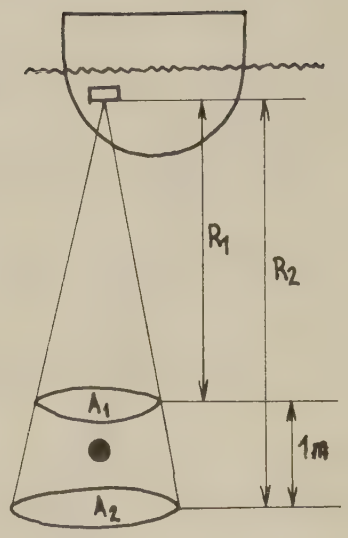

Figure 6. Determination of solid angles

When we have calculated the performance (SL + VR), we can calculate the back scattering strength of the calibration spheres. To do that we introduce in the echointegrator QD the values obtained (SL + VR = SL and VR = 0) and we make an integration of a 1 meter layer including the sphere and in absence of any other echo as from fishes or plankton, we get an experimental S_v value.

Later we calculate the theoretical S_v knowing the TS of the sphere.

$$S_v = TS + 10 \log V_o \qquad (16)$$

It is necessary to calculate the solid angle which depends on the transducer characteristics (directivity coefficient, ψ) (see fig. 5).

$$A_1 = R_1^2\ \psi$$

$$A_2 = r_2^2\ \psi$$

Then:

$$V_o = \frac{R_2 - R_1}{3}(A_1 + A_2 + \sqrt{A_1 A_2}) \qquad (17)$$

In that way we can calculate S_v and see if it corresponds to the experimental value.

1/ Example in Appendix J, the echolevel U of 0.17 V_{p-p} converted into V_{rms} in dB gives 20 log 0.17 - 20 log $2\sqrt{2}$ = -15.4 - 9.0 = -24.4.

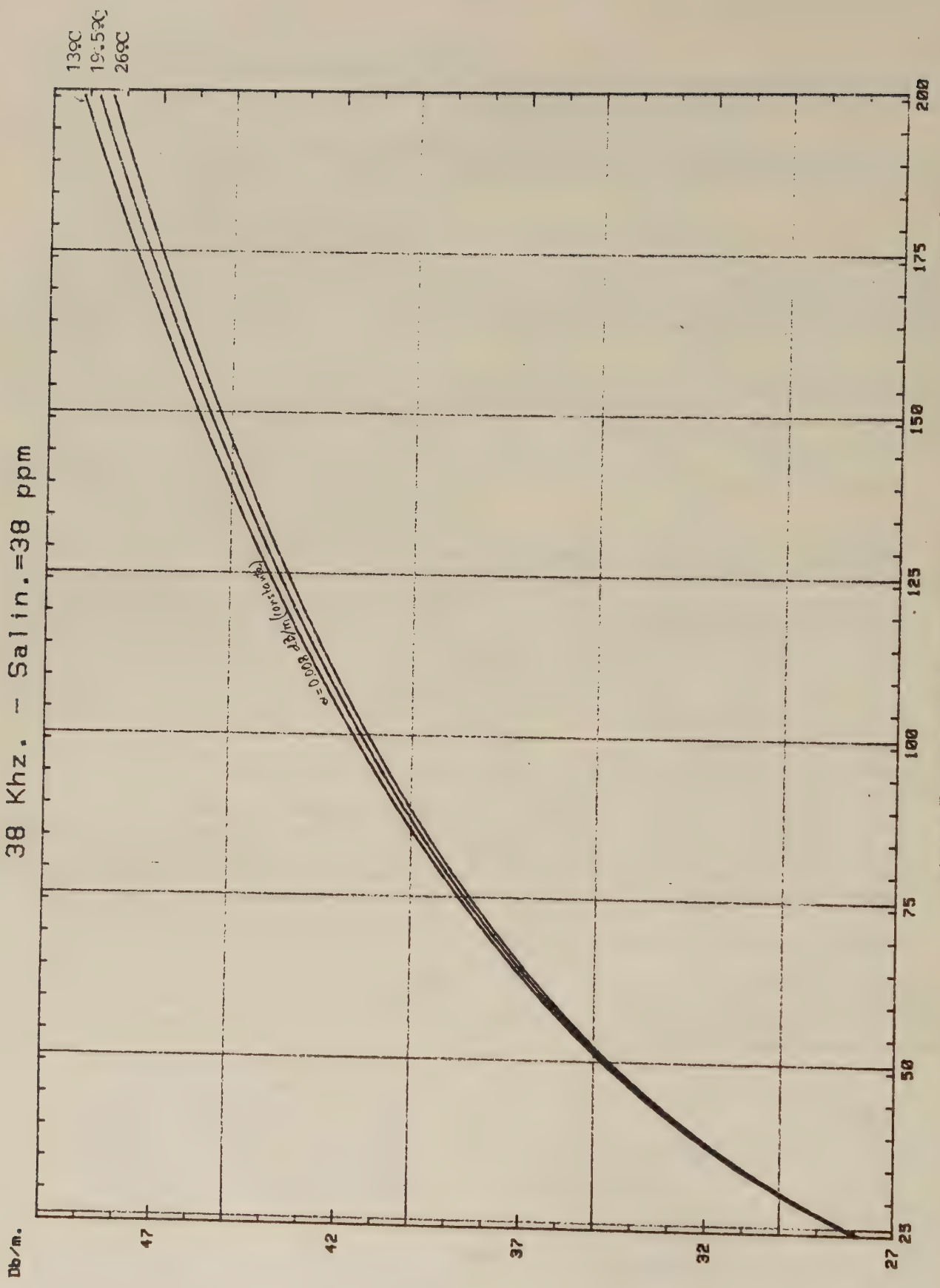

Figure 7. Example of a TL curve.

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APPENDIX J / ANNEXE J

WORK SHEET FOR ECHOSOUNDER CALIBRATION USING A TUNGSTEN CARBIDE SPHERE

	Vessel:	ODON DE BUEN	Date:	11 Nov. 1982
	Place:	Cabrera	Depth:	20 m
	Echosounder Type:	EK S 38	Transducer:	69 M
	Frequency:	38 kHz	TS of Sphere:	- 42,3
1.	Water Temperature:	18° C	Sound Velocity (c):	1 500 m.p.sec.
	Depth of Sphere (t):	16 ms	$r = \frac{\tau c}{2}$ =	12 m

			40 log R		20 log R		
2.	TVG Constant (2 TL 40, 2 TL 20)		99,1		64,6		dB
3.	2 Way Transm Loss to Depth		43,4		21,8		dB
4.	TVG Attenuation at Depth		55,7		42,8		dB
5.	Output reference level		1.0		1.0		Vp-p
			0		0		dB
6.	Output level, measured		1.62		1.85		Vp-p
			4.2		5.1		dB
7.	Deviation 6 - 5 = Δ TVG		4.2		5.1		dB
8.	GAIN	Selected	10	20	30	40	
		Measured					
	Output power		High	Low	High	Low	
	Pulse Duration		0,6		0,6		misc.
	Receiver Bandwidth		wide	wide	wide	wide	
9.	Echo Level U		0.17		0.68		Vp-p
	$20 \log \frac{U}{2\sqrt{2}}$		-24,4		-12,4		dB
10.	SL + VR		112,8		111,0		dB
	SL + VR = U - TS + 2 TL 40 - G - ΔTVG						
	SL + VR = U - TS + 2 TL 20 - G + 20 log r - ΔTVG						

MINIMUM DEPTH TO SPHERE-USING 20 dB ATTENUATOR

$$r = 10^{\frac{(S + M + 10 \log P + TS + 17,8 - U)}{40}} \text{ m}$$

S and M are transducer data
P = Transmitter output power
U = Maximum input signal to receiver

APPENDIX K / ANNEXE K

WORK SHEET FOR ECHOSOUNDER CALIBRATION USING A COPPER SHPERE

	Vessel:	ODON DE BUEN	Date:	11 Nov. 1982
	Place:	Cabrera	Depth:	20 m
	Echosounder Type:	EK-S 38	Transducer:	69 M
	Frenquency:	38 kHz	TS of Sphere:	-33,7
1.	Water Temperature:	18° C	Sound Velocity:	1 500 m.p. sec.
	Depth of Sphere:	16,1 ms	$R = \frac{T\ c}{2}$:	12,1 m

			40 log R		20 log R		
2.	TVG Constant (2 TL 40), 2 TL 20)		99,1		64,6		dB
3.	2 way transm loss to depth		43,6		21,9		dB
4.	TVG attenuation at depth		55,5		42,7		dB
5.	Output reference level		1.0		1.0		Vp-p
			0		0		dB
6.	Output level, measured		1.62		1.85		Vp-p
			4.2		5.1		dB
7.	Deviation 6 - 5 = △TVG		4.2		5.1		dB
8.	GAIN	Selected	10	20	30	40	
		Measured					
	Output power		High	Low	High	Low	
	Pulse Duration		0,6		0,6		misc.
	Receiver Bandwidth		Wide	Wide	Wide	Wide	
9.	Echo level U		0.48		1.92		Vp-p
	$20 \log \frac{U}{2\sqrt{2}}$		-15,4		-3,4		dB
10.	SL + VR		113,2		111,5		
	SL + VR = U - TS + 2 TL 40 - G - △TVG						
	SL + VR = U - TS + 2 TL 20 - G + 20 log r - △TVG						

MINIMUM DEPTH TO SPHERE-USING 20 dB ATTENUATOR

$$r = 10^{\frac{(S + M + 10 \log P + TS + 17,8 - U)}{40}} \text{ m}$$

S and M are transducer data
P = Transmitter output power
U = Maximum input signal to receiver

APPENDIX L / ANNEXE L

METHODS AND SHORTCOMINGS OF LIVE FISH CALIBRATION

by

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I. INTRODUCTION

To obtain an accurate estimate of insonified fish densities, the received echosignals must be correctly scaled by a factor "C", called Calibration Constant. The measurements of "C" is one of the most important and critical operations of an echo survey.

A widely used method of determining "C" is the calibration on an artificial fish concentration in a net cage (Direct Calibration). This method assumes that the density, species composition, behaviour and insonified volume of the encaged fish may be directly extrapolated to the conditions encountered in situ i.e. during the survey.

Live fish are placed in a cage under an external transducer; special measures must be taken during the operations of catching and supplying fish into the cage to guarantee not only a high survival rate but also their good physical condition during the calibration process. The dimensions and shape of the cage should ensure a natural fish behaviour. The range of integration must be set so as to exclude echosignals from the cage structure. The contribution of the net cage is estimated separately from the integration of echo signals returned by the cage without fish.

When measuring, it is assumed that the fish in the cage are uniformly distributed in the volume insonified by the echosounder.

A series of measurements is made with different numbers of fish in the cage and an approximately linear relationship between the sum of integrated echosignals and various densities of fish (regression line) is calculated. The first coefficient of the regression line of density-on-integrator readings designates the Calibration Constant referred to the external transducer.

Finally, the results of the calibration process are converted (Intercalibration)to the hull mounted transducer, used during the echo-survey.

At present, the calibration procedures seem to suffer of the following:

- Shortcomings in averaging target strengths: These include a) the neglect of a difference in target strengths for different types of behaviour of the fish in the net-cage, b) the neglect of relating the scattering characteristics of fish and their physical states at different depths of the cage and c) disregard of fish orientation and the distribution of their orientations in the cage.

- Shortcomings in neglecting the form of the spatial patterns of the fish in the cage, the changes of those patterns during the calibration process, the distribution of fish within the above patterns.

- Shortcomings in relating volume density of the artificial concentrations in the cage and the packing density of schools, layers, accumulation determined by empirical data.

Moreover, there is at present a lack of standardization in calibration measurement procedures, instrumentation and equipment, which prevents an objective analysis, verification and comparison of the results obtained by various authors. Therefore, the fundamental assumption of the method of extrapolating the results of the Direct Calibration for the in situ conditions may often be erroneous.

In this paper, after a review of the calibration process that is aimed at giving the parameters that influence it and the fundamental relationships of the method, some behaviour of the encaged fish and some forms of their spatial patterns in the cage are analyzed to interpret their influence on the calibration measurements.

The specific questions made are:

(1) What types of behaviour characterize the encaged fish and how do they influence the calibration measurements ?

(2) Which distribution patterns characterize the artificial concentration of the fish and how do they influence the calibration measurements ?

(3) What insights do the answers to the questions (1) and (2) provide about the procedures and the equipment to be used in the calibration process ?

II. A REVIEW OF THE PARAMETERS THAT INFLUENCE THE CALIBRATION PROCESS

The calibration process involves three sets of parameters:

- Instrument constants
- Fish target parameters
- A combination of beam pattern and fish concentration parameters.

The instruments constants are:

- The integrator constant K (mm/V^2s)
- The echosounder constant C_o (V^2m^2).

Theoretically, they could be calculated on the basis of the instrument specifications provided by the manufacturer. However, as the manufacturer-specified parameters may be inaccurate and/or may vary during the useful life of instruments, it is necessary that the instrument constants be measured accurately before the calibration process.

The fish target parameters are:

- The back scattering cross section σ (m^2)/the target strength TS
- The average weight per fish $\overline{W}$ (g)/the average length per fish $\overline{l}_f$.

The back scattering cross section and the target strength are inter-related in the sense that the target strength is the logarithmic transformation of the back scattering cross-section 1/.

The backscattering cross-section, very roughly, is proportional to $\overline{l}_f^2$, the weight is proportional to $\overline{l}_f^3$, therefore the Calibration Constant is approximately proportional to l_f ($C = \overline{W}/\overline{\sigma}$).

Such succession of simplifying assumptions and neglect of the fish species and its scattering properties is common in the literature. (Aglen and Myklevoll, 1982). In reality the fish target parameters must be considered as random variables. In fact, they depend on many factors that alter randomly the echo amplitude at the receiver. Among them we list:

(1) the species-specific characteristics: body shape and anatomy; the impedance contrast of the fish body of a certain species/size and placed at a certain depth relative to water.

(2) the different lengths of the encaged fish and of their swimbladders referred to the wave length used in the experiment.

(3) the biological and physical conditions of fish in the cage. Individuals of the same species and size may show differences in their shapes and in inflation of their swimbladder 2/.

(4) the behaviour of fish during calibration measurements. Three types of behaviour have been identified during the calibration process:

- Wild behaviour. Fish struggle to get out of the net cage. Horizontal and vertical displacements are large and wild. This behaviour generally occurs just after the fish are placed in the cage or whenever divers approach it.

1/ The back scattering cross-section is different from the scattering cross section for a complicated scattering target like a fish. The conversion of the back scattering cross section to the scattering cross-section is easy only if the scattering is isotropic. Here we indicate as backscattering cross section what we measure during the calibration process as described later in para 3 and 5.

2/ The X rays used recently on some fish to identify the swimbladder characteristics have confirmed this hypothesis.

- Still behaviour. Fish are without apparent movement. This behaviour is characteristic of injured fish or, sometimes happens at night.

- Lively behaviour. Fish move, changing positions smoothly and regularly. This behaviour is considered to resemble that of a free fish.

(5) The aspects of fish as viewed form the observation point (i.e. form the transmitting and receiving beam pattern): dorsal/ventral/side/head/tail aspect.

(6) the motions of fish relative to the observation point. Alive fish rotate and flex their bodies so that the orientation (Law, roll, pitch), apparent shape and aspect of each fish in a given position change from measurement to measurement.

All the above factors are more or less strongly correlated random variables. In addition to the problem of random echo amplitudes from a fish in a given position in the transducer beam, fish are distributed at some random positions in the echo sounder beam and change their position from moment to moment. This gives an additional random factor that alters the echo amplitude at the receiver. To reduce this last variability, dimensions and shape of the net-cage must be accurately designed on the basis of the echosounder beam as described in section 5.

The combination of the beam pattern and the fish concentration pattern determine the active volume of the space directivity diagramme i.e. the intersection fo the spherical wave layer (detection zone) and the fish concentration layer (cage geometry). The detection zone can be determined by the parameters of the real acoustic beam, the artificial concentration depth and thickness. It can be expressed by the following formula:

$$V \simeq K_f \theta'_n \theta''_n h r^2 \left(1 + \frac{h}{r} + \frac{h^2}{r^2}\right); (m^3) \qquad (1)$$

where:

K_f = coefficient of form of the detection zone, equal to the ratio of the horizontal sectional area of the detection zone to the area of the circumscribed rectangle.

θ'_n, θ''_n = the acoustic system directivity angles formed by the level of intensity n ($0.1 \leqslant n \leqslant 0.5$) when transmitting/receiving in longitudinal and transversal plans respectively.

h, r= the thickness and depth of the artificial concentration. The thickness of the net-cage should be at least 5 times larger than the vertical dimension of the scattering element of space ($c\tau/2$).

If the cage has the geometry expressed by (1), with appropriate values of n, h, r, and if the fish concentration can be assumed uniformly distributed in it, then the active volume and the detection zone coincide; the volume density of fish can be easily calculated by the expression:

$$\rho_v = n_f/V \quad (\text{number of fish/m}^3) \qquad (2)$$

However, if the spatial pattern of the artificial fish concentration is different from the cage geometry, then the active volume must be calculated (where possible) tentatively and the volume density ρ_v depends in a complicated way on the parameters of the beam and fish contration patterns.

The volume densities of the fish in the cage must be kept within the expected limits of the packing densities of freely swimming fish schools. They can be determined by using empirical data (for instance purse seine data) or by the formula:

$$\rho_v \simeq (10^6/\bar{l}_f^3)(k^3 + k^2) \qquad (3)$$

where

$\bar{l}_f$ = average length per fish (cm)

k = formation coefficient, that is a function of the species (k = 1 to 3 for a wide range of small pelagic fish).

However, only if the densities of the concentration in the cage are conform to Rayleigh scattering, the calibration measurements can be used to compute the back scattering cross section/target strength or vice versa, as indicated in the sections 3 and 5.

According to Rayleigh's law, the mean intensity of echosignals from a concentration is equal to the sum of intensities of elementary reflection from individual fish falling into impulse volume if ρ_v satisfies the following condition:

$$10/(\frac{c\tau}{2})\ S \leqslant \rho_v \leqslant 1/(c\tau)\bar{l}^2_f \qquad (4)$$

where:

S = horizontal sectional area of the cage (m^2). For instance if the cage has the geometry expressed by (1), then $S = K_f$

$.c\tau/2)$ = thickness of the scattering element of space (m); 1 .c= 1 500 m/s; τ= pulse length (s)

$\bar{l}_f$ = mean size of fish in the cage (m).

With a lower number of fish in the cage, the Rayleigh law is disturbed by considerable fluctuations, due to a non-uniform distribution of scatterers in the detection zone of the echo sounder.

With a denser concentration in the cage (i.e. when the distance between neighbouring fish is commensurable with acoustic wave length), the scattering fields of individ al fish affect each other and a "multiple scattering phenomenon" takes place (i.e. each fish, in scattering the acoustic wave, insomifies nearby fish targets which also scatter part of the energy and so on). The resulting echosignals show signs of coherence, of interference and diffraction that are not considered in the linear model based on the Rayleigh law.

Therefore the calibration measurements depend not only on the acoustic properties of individual fish but on the density of their distribution, that influence the pattern and intensity of the scattering field.

III. A REVIEW OF THE EXPRESSIONS USED TO COMPUTE THE CALIBRATION CONSTANT

Let $\bar{\rho}_B$ be the average biomass of fish (t/nmi^2) and $\bar{M}$ the average echo integrator output (mm ref 1nmi), the calibration constant can be defined by:

$$C = (\bar{\rho}\ /\bar{M});\ ((t/nmi^2)/mm)\ ref.1nmi \qquad (5)$$

There is a number of ways in which the Calibration Constant (i.e. the scale factor of the density recorder) can be expressed.

1. Johannesson and Losse, 1977:

$$C = 3430\ \bar{W}\ \bar{\rho}_v\ \frac{\Delta h}{\bar{M}} \qquad (6)$$

where:

$\bar{\rho}_v$ = the average density of fish per unit of volume; ($1/m^3$)

$\bar{W}$ = average weight per fish; (g)

Δh = integrated layer; (m)

$\overline{M}$ = average echo integrator output (deflection); (mm ref 1nmi)

2. Stepnowski and Burczynski, 1981:

$$C = 3430\ \overline{W}\ C_{ES}\ C_{EI}\ C_F; \qquad (7a)$$

where:

C_{ES} = echosounder constant = $10^{0.1 C_1}$; C_1 is the well known "Simrad Constant";
$C_1 = -SL - VR - 10\log(\alpha\tau/2) + 20\log R_{max} + 2\alpha R_{max} - 10\log\Psi$;
SL, VR are the source level and voltage response parameters determined with a calibrated hydrophone/standard sphere; R_{max} is the TVG range boundary (m);
Ψ is the "equivalent beam pattern";

C_{EI} = echo integrator constant = $10^{0.1(V_{01} - A)}$; $\overline{V}_{01}$ is a constant value corresponding to the mean value of echointegrator output; $\overline{V}_{01} = \overline{V}_0 + 10\log\Delta h - 10\log M$ is obtained for a unit integrator deflection ($\overline{M}$ = 1mm) and for a unit integrated layer (Δh = 1m); in the SIMRAD QM integrator $\overline{V}_{01}$ = -2 dB;

C_F = coefficient related to the fish characteristic = $10^{-0.1\ \overline{TS}}$; $\overline{TS}$ = average target strength; $\overline{TS} = m\log\overline{l}_f + b$; $\overline{l}_f$ = average length of fish (cm); m, b experimental coefficient calculated for a given species at the wave length used in the experiment through the regression-line method.

The expression (7a) can be easily expressed as a function of fish length or of average target strength per 1 kg (TS_{1kg})

$$C = 3430\ \overline{W}\ C_{ES}\ C_{EJ}\ C_b\ \overline{l}_f^{-0.1m} \qquad (7b)$$

where:

$C_b = 10^{-0.1b}$

$C = 3430\ C_{ES}\ C_{EJ}\ 10^{-0.1\ \overline{TS}_{1kg}}$

Where:

$\overline{TS}_{1kg}$ = average target strength per 1 kg of fish; $\overline{TS}_{1kg} = \overline{TS} - 10\log\overline{W} = \overline{TS} + 10\log n_{1kg}$

3. Vozobyov, Ivanov and Suomala, 1980

$$C = 3430\ \overline{W}\ \left(\frac{A^2}{C_o}\right)\left(\frac{1}{\tau K}\right)\left(\frac{1}{C_v}\right)\left(\frac{1}{\sigma}\right)\ \Delta h \qquad (8)$$

Where:

A = receiver amplification gain/TVG; (m^2)

C_o = echosounder constant; (m^2V^2)

K = echointegrator constant; (mm/V^2s)

C_v = constant of the insonified volume at a given τ pulse duration = $\frac{\pi}{8}\ \theta'_{0.1}\ \theta''_{0.1}\ C\tau =$
$\Psi(\phi)\ C\tau$; (m^2)

$\theta'_{0.1}$ $\theta''_{0.1}$ = directivity angles of the hydroacoustic transducer at the tenth power level on the longitudinal and transversal plane respectively; (rad)

$\bar{\sigma}$ = backscattering cross-section of a single fish averaged for all the fish falling in the impulse volume (C_v; (m^2)

4. Kalikhman, Tesler and Yudanov, 1981

$$C = 3430\ W \left(\frac{A^2}{C_o}\right) \left(\frac{1}{\tau K}\right) \left(\frac{1}{\Omega}\right) \left(\frac{1}{6}\right) \qquad (9)$$

where:

Ω = active volume of space directivity diagram determined by the cage geometry, if some assumptions are satisfied (i.e. fish concentration is assumed uniformly distributed in the whole volume of the cage).

σ = backscattering cross section of individual fish on acoustic axis.

All the above expressions can be transformed from units ((t/nmi^2)/mm) ref 1n mi to units of ((1/m^2)/mm) ref 1n mi dividing C by 3430 $\overline{W}$, or to units of (1/m^2/mm), that is to density in the cage, dividing C by 3430 $\overline{W}$ n, where n is the number of transmissions during an integration period (i.e. period corresponding to 1nmi at a given vessel speed).

The equation (6) can be used only in one way, that is the direct estimation of the calibration constant C. It does not allow any analysis, verification or comparison of the results.

The equations (7), (8) and (9) can be used in different ways.

- When the backscattering cross section/target strength and active volume (9) are known, the calibration constant C can be determined;
- When the fish density and active volume (9) are known, the backscattering cross section/target strength can be determined;
- In the expression (9) when the fish density and cross section/target strength are known, the active volume Ω can be determined.

Those uses of the expressions (7), (8) and (9) assume that the densities of fish concentrations in the cage are conform to Rayleigh scattering. If it is so and the relationships between fish parameters (TS or σ; l_f; W) are known for the species under examination (two rather broad assumptions), then the calibration constant C can be deduced/verified/compared through the formulas (7), (8) and (9). Of course the instrument constant must have been determined previously.

The expressions (6) and (7) use the equivalent beam pattern in the echosounder constant C_{ES}, that leads to errors in determining the fish concentration density both in resolved and unresolved fish registration (Kalikhman, Tesler and Yudanov, 1981). The expression (8) introduces the constant of the insonified volume C_v, that seems a more accurate approximation of the true beam pattern.

The expression (9) needs the determination of the active volume Ω of the space directivity diagram (i.e. the intersection of the detection zone and the fish layer). The active volume is a variable function of the parameters of the echosounder together with fish concentration.

The expressions (6), (7), (8) assume that the fish concentration forms a plane-parallel-layer. The formula (9) may be used also if the form of the concentration is different from that of a plane-parallel layer; however, in this case, the estimation of active volume is very difficult and can be done only tentatively.

All the cited expressions to compute C assume that the integrated section of the insonified layer is homogeneous. If it is not, the determination of the value of C/fish density/backscattering cross-section through the above expressions can lead to considerable errors.

IV. THE INSTRUMENT CONSTANTS

The first step in the calibration procedure is the determination of all the equipment parameters. Referring to the expression (9), we have the following expressions of K and C_o.

- The echo integrator constant K is determined by the input of a certain voltage from a signal generator (U) and the output of a certain deflection (M), that is:

$$K = \left(\frac{M}{U^2}\right) \quad \frac{C}{2dn} \; ; \quad (mm/V^2 s) ; \qquad (10)$$

Where:

U = rms signal voltage; (V)
M = deflection; (mm)
d = integrated layer; (m)
c = sound velocity; (1500 m/s)
n = number of transmissions during the integration period

- The echosounder constant C_o can be determined either with a calibrated hydrophone or with a standard sphere. In this last case the expression for determining C_o is:

$$C_o = ((U_{st}^2 \, r_{st}^4)/\sigma st) \, 10^{0.2 \alpha \tau_{st}} ; (m^2 V^2) \qquad (11)$$

where:

U_{st} = rms voltage of standard sphere echo signal on the transducer; (V)

r_{st} = distance from the transducer to standard sphere; (m)

σ_{st} = standard sphere acoustic cross section; (m^2)

α = coefficient of the spatial sound attenuation in water; (dB/m)

The determination of C_o with a calibrated hydrophone regards the measure of two parameters known as source level (SL) and voltage response (VR):

SL = 20 log (P/Po); transmitting conditions
VR = 20 log (k/ko); receiving conditions

Where:

p = (Upp r 0.707)/(k_h $r_1$2); transducer pressure; (Pa)

p_o = 1μ Pa standard level of pressure

k = (Upp r)/(V_9 r_1 η_e); voltage response; (Pa/V)

k_o = 1V/1 Pa; standard level of voltage response

Upp = peak-to-peak echo voltage; (V)
r = the range between the hydrophone and the transducer; (m)
k_h = hydrophone receiving voltage response; (V/Pa)

r_1 = unit distance; (1m)

V_g = echovoltage of the measuring generator; (V)
η_e = hydrophone transmitting voltage response; (Pa/V)

The constant C_o is determined by the expression:

$$C_o = (p^2 k^2 r_s)\,(1/4\,\pi);\,(V^2 m^2) \qquad (12)$$

The receiver amplification gain/TVG is measured separately (A in the expressions (8) and (9).

A discussion on the echo integrator and echo sounder parameters and in particular an analysis of the advantages/disadvantages in the hydrophone and standard sphere methods is beyond the limits of this paper.

V. THE FISH TARGET PARAMETERS

The measurement of the Calibration Constant involve three fish parameters, correlated to each other: the length of fish l_f, the weight of fish W, the backscattering cross section/target strength TS. Preferably the fish in the cage should be of the same species and, as far as possible of the same size.

Three different types of behaviour have been identified during the calibration process defined as: "still", "lively" and "wild". They may determine a wide range of values in the measurements of the TS of a single fish.

The acoustic cross-section/target strength TS of an individual fish can be determined by the expression (9), where the concentration density and the active volume are obtained respectively from the number of fish supplied in the cage divided by the cage volume, and from the geometry of the cage. The device constants have been measured separately.

It is assumed that the fish are statistically uniformly distributed in the whole volume of the cage, which is a very broad assumption as explained in section 6.

Measurements taken on an artificial concentration of sardines (Sardina pilchardus (Walb.)) fairly homogeneous in weight ($\overline{W}$ = 43 g) and length ($\overline{l_f}$ = 17 cm), gave the following results under the three types of behaviour:

If the fish were "still" , about 35% of the TS measurements were regrouped into a bin of 1 dB amplitude of - 44dB value. The remaining measurements were distributed between -47dB and -45 dB (50%) and between -43 dB and -41 dB (15%).

If the fish were "lively" about 50% of the TS measurements spread between -42 dB and -39 dB. The remaining measurements were distributed between -48 dB and -43 dB (30%) and between -38 dB - 36 dB (20%).

If the fish were "wild", about 65% of the TS measurements spread between -44 dB and - 36 dB. The remaining measurements were distributed between - 49 dB -45 dB (20%) and between -35 dB and -33 dB (15%).

The geometry of the cage used in the experiment had the same shape as the detection zone, described by the formula (1), where the directivity angles of the transducer were at one tenth of the power level (n = 0.1). The distance of the upper surface of the cage from the transducer was 5 m. The height of the cage was 2 m.

There is some experimental evidence that a cage geometry different from the detection zone increases the echo fluctuations, mostly when the fish are behaving "lively". In fact the fish with lively behaviour swim along trajectories parallel to the lateral surface of the cage and only if the cage is fitted to the beam pattern Ψ (Φ), these trajectories follow approximately the curves Φ = const.

The regression line equation between TS and the fish length $\overline{l_f}$ fits the measurements on the fish moving only a little ("Still" behaviour); a fish under "still" behaviour has a narrow range of echo amplitudes and is approximately like a standard sphere of appropriate radius.

However the "lively" behaviour is probably the nearest to a free fish; if it is so, one should model the cross-section/TS of a fish body taking into account the body movements (for instance introducing a scattering length of the fish, i.e. an array of points, probably interfering each other

during the movements of a fish, that should be deduced by the anatomy of a live fish in its normal attitudes and behaviour). Consequently the measurements of the Calibration constant should involve the Probability Density Function of a set of measurements, because during the calibration process the fish behaving "lively" rotate and flex their bodies at a large range of angles/amplitudes.

A further problem, that till now has not been sufficiently investigated, is the influence of the depth at which the cage is placed on the backscattering cross section of a fish and on its behaviour. It is likely that the shape and inflation of the swimbladder as well as the fish physical state and behaviour change with the depth and those changes must be related with the particular anatomy (species and size) of the fish under examination).

In this case the cross-section should be modelled not only on the basis of fish behaviour and movements but also take into account the depth at which the encaged fish are placed.

VI. THE BEAM PATTERN AND FISH CONCENTRATION PARAMETERS

If the fish are distributed statistically uniformly in the whole volume of the cage, the active volume of space directivity diagram Ω in the expression (9) is determined by the cage geometry. Unfortunately the above assumption seems valid only when the fish have a "still" behaviour (i.e. when they are behaving in a way that, probably, differs from that of a free swimming fish).

If the fish are behaving in a "wild" way, they move in any direction (random strategy) and their horizontal and vertical movements/displa ements are large/chaotic.

The fish that have a "lively" behaviour, seem to adopt a group strategy; they swim along trajectories parallel to the lateral surface of the cage and, at the same time, they form spatial patterns (strongly influenced by the shape of the cage) that undergo changes during the calibration process in relation with the changing of packing density, time of day (light), and other physico-chemi al situations (currents, temperature, transparency of water).

In general, the form of spatial patterns seems to demonstrate that the fish behaving "lively" try to avoid the lateral and upper surfaces of the cage. Very roughly the forms of the spatial patterns, in a frustum shaped cage two meters high, may be assimilated to:

- spheroids/ellipsoids when the packing density is low (<15 fish/m^3)
- blunted cones/cylinders when the packing density increases.

The dimensions of the above patterns depend on the time of day (at night they expand up to 10 cm from the net fo the cage) and the transparency of the water. The currents cause strong distortions both in the spatial patterns and in the swimming trajectories of fish.

It was observed in many calibration experiments that the day-time set of measurements were nearly two times higher than those taken at night. This difference almost disappeared if surface lights were used at night. It should be noted that, for experiments carried out with "wide beam", the difference between night/day measurements is generally small. A possible explanation is in a combination of the fish behaviour (at night fish are near to the "still" behaviour) with the features of the fish patterns, that at night expand and in day time contract their dimensions.

Another open question is the fish distribution within the spatial patterns (i.e. the internal structure of the patchiness) and, consequently, within the beam angle. The divers observed that the fish tend to pack in a narrow layer (some tens of centimeters) on the surfaces of the described spatial patterns (ellipsoids, cylinders, etc), while they are more and more dispersed towards the centre of the cage. This phenomenon increases with decreasing the packing density so that, when the fish density is below certain limits depending on the species (for instance < 50 fish/m^3, for the sardines), it can cause strong bias in the measurements.

At present, it seems indispensable that the measurements of the Calibration Constant are associated with the information on the spatial patterns and the fish distribution within them, so that each set of measurements can be referred to a particular situation in the cage.

The above problem can be solved using two automatic photocameras, that must be lowered, carefully and regularly, above the cage and at the side of the cage.

The photocamera pointed laterally should provide information on the vertical shape and dimensions of the fish patterns in the cage (geometrical data on the artificial concentration). It is particularly important to valuate the vertical displacement of the tip apex of the pattern from the upper surface of the net as well as the length of the tip, so that they can be excluded from the integration range Δh.

The photocamera pointed down should provide a collection of data on the fish density, orientation and distribution of their orientation that could be compared with the echo intensity measurements (density data on the artificial concentration). The average density of the artificial aggregation can be estimated using the following formula:

$$\rho_v = \frac{\sum n}{M.V} \quad ; \text{ (fish/m}^3\text{); (from V.A. Ermolchev and Zaferman, 1981)} \qquad (13)$$

where:

$\sum n$ = number of fish in all the photos
N = number of fish taken during an appropriate period of the calibration process
V = observed volume in one photo = $K_c\, r_c^3$; K_c = camera constant provided by the manufacturer; r_c = maximum distance between a fish and the camera, at which a fish image can be identified and its relative scale estimated referring to the average length of a fish.

A preliminary experiment has been carried out recently with an automatic camera looking down but unfortunately it was not successful. In fact the use of a camera caused the following inconveniences:

- the fish were alerted and frightened whenever the camera was lowered.
- the range of the camera was too limited and strongly influenced by the transparency of the water, which is poor in the Adriatic sea. This difficulty was particularly evident at night, when the use of subwater lamps was necessary.

VII. CONCLUSION

The experiments on encaged fish carried out since 1975 have displayed the variability of the echo intensity measurements as a consequence of different behaviours of the fish. Compared to the echoes from a reference sphere, the echoes from live fish, that swim in the cage, rotating and flexing their bodies, have a narrow range of amplitudes. Only fish that are behaving in a very still way have a narrow range of amplitudes comparable to those of a reference target. Therefore the simple model that relates the length of a fish to its target strength seems unsatisfactory for live fish that are free to move and to swim. Perhaps models that relate the sound scattering characteristics and the anatomy of a fish in a certain physical condition may provide better results. In fact it is possible that the swimbladder changes in shape and inflation, while a fish changes behaviour, attitude, depth. In this case, the target strength of a fish should be referred to an average of sound scattered from the various configurations that a fish, with a certain anatomy and behaviour, placed at a certain depth, is able to assume. Consequently, the determination of the Calibration Constant should require several sets of measurements, and each set should involve the probability density function.

The method of direct calibration presents a lack of accuracy connected mostly with the complexity of associating the echo intensity measurements with the information on behaviour, spatial patterns and distribution of fish in the cage.

Improvements in this direction can be obtained using, regularly, automatic photocameras aimed at the top and side of the cage.

Another possible error in the Calibration Constant may be introduced by the intercalibration between the external transducer and the vessel transducer. This last step of the calibration process has not been examined in this paper. However, in applying the results of the direct calibration measurements to the quantitative estimation of biomass there are two advantages to consider.

The first is that many repeated measurements of the echoes from live fish that swim, change behaviour and attitudes give probably an average of the sound effectively scattered by the fish during the acoustic survey better than models of fish based only on laboratory experiments.

The second is that the direct calibration allows to simulate the effective packing density of the schools freely swimming, also when it is beyond the Rayleigh law. This is not possible using linear models that do not consider effects such as interference, diffraction, coherent and multiple scattering.

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APPENDIX /ANNEXE M

OBTAINING ECHO INTEGRATORS INTERCALIBRATION COEFFICIENTS BY JOINT NAVIGATION OF RESEARCH VESSELS

by

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I. INTRODUCTION

In view of an acoustic survey to evaluate the pelagic stocks of the Spanish Alboran Sea 1/ a new acoustic system consisting of echo sounders SIMRAD EK 400 (38 and 120 kHz) and a SIMRAD QD digital echo integrator was installed on board the R/V "CORNIDE DE SAAVEDRA". The density coefficient or conversion factor C had not yet been calculated for this equipment. This coefficient allows the transformation of the echo integrator output relative values ("millimeters") in absolute values of biomass in tons or numbers of fish. It is usually obtained by means of direct calibration experiemnts using the method of live fish in a net cage (Johannesson and Losse, 1977) or by counting individual fish on the echogram (Midttun and Nakken, 1968). Another system consists of the intercalibration with another research vessel that has a reliable C coefficient. For that purpose an intercalibration was peformed by the R/V "CORNIDE DE SAAVEDRA" and the R/V "DR. FRIDTJOF NANSEN"; the latter belongs to the Norwegian Agency for International Development (NORAD) and was operated by the Institute of Marine Research, Bergen for a joint UNDP/FAO/NORAD project. The intercalibration took place in waters of South Morocco.

Three months later, a joint acoustic survey was made to evaluate the Portuguese-Spanish sardine stock (VIIIc-IXa ICES division). The cruise was made by the research vessels "NORUEGA" (Portugal) and "CORNIDE DE SAAVEDRA". In order to compare the relative output values of the echo integrators of both vessels, an intercalibration navigation was made off the coast of Galicia. The present paper describes these experiments and discusses their results.

II. METHODS

The method of echo integrator output values intercalibration by means of a joint navigation of two research vessels on fish or plankton concentrations has been described by, among others, Rottingen (1982). The best situation to carry out such intercalibrations is when the vessels can sail over a layer of scattered fish at a medium depth. Also plankton concentrations can be used as targets. If schools of fish are present it is unlikely that both vessels would register exactly the same schools and densities and it is thus impossible to obtain a good correlation between the outputs of the echointegrator.

The disposition of both ships during the intercalibration navigation is shown in figure 1. The distance of 0.5 nautical miles between the vessels insures the lack of noise from the other ship (propellers, engine...), prevents interference from echo sounders of the same frequency transmitting from the other vessel, and gives security to navigation. The vessel astern must position herself some 10^{o} to port or starboard of the other vessel to avoid her wake and air bubbles from the propellers. The more powerful and manoeuvrable vessel must place herself behind the other one and take care to keep a constant distance and angle between herself and the other ship.

The experiment must be carried out in the best possible weather conditions as the presence of bubbles produced by the waves in rough weather causes dispersion of the sound energy. The pitching and rolling of the boats also make intercalibration difficult.

There must be a close coordination between the teams of both vessels in order to obtain comparable samples. That is to say, that the output echo integrator values are obtained over the same units of distance navigated (normally over the same nautical mile). This can be achieved by two different methods:

(a) when the log of the first vessel shows 0.5, a signal is radioed to the second boat, which resets manually her echointegrator. The distance between the vessels being 0.5 nautical mile, the log of the vessel astern will be 0.0. From then, every time the forward vessel passes a 0.5 mile in her log, the second vessel will reset her echointegrator. The forward vessel will do the same every full mile. In fact, both ships are regulated by the forward log.

(b) If the boats sail at a constant speed, comparable samples can be obtained in terms of units of time. If, for example, it is decided to read the echo integrators every ten minutes, the

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1/ See Appendix N.,

forward vessel will reset every time that the minute unit in the watch marks 0, and the vessel astern will do the same when the minute unit marks 5. The echograms thus obtained correspond to the same distances navigated and their integrator output values can be directly compared.

For both methods, a close communication between the ships (by VHF) is needed.

III. RESULTS

3.1 Intercalibration between R/V "CORNIDE DE SAAVEDRA" and R/V "Dr. FRIDTJOF NANSEN"

The navigation took place on 2 and 3 April 1982 off South Morocco. The acoustic system of the "CORNIDE" consisted of an echsounder EL 400-38 kHz and a digital echo integrator QD. The system on board the "NANSEN" was an echo sounder EK-S 38 kHz connected to an analog integrator QM-MK II.

The settings of the instruments are shown in Table I. For both vessels these were the standard working positions during their cruises.

The acoustic calibration of both systems had been carried out previously: a couple of weeks before on the "CORNIDE", two months before on the "NANSEN". A standard copper sphere was used on board both vessels. Calibration was repeated on "CORNIDE" at mid-cruise, using a Brueland Kjoer hydrophone this time. The results were exactly the same. Calibration measurements are shown in Table II.

The fundamental equation in acoustic stock abundance estimation is:

$$\rho = C \times M \qquad (1)$$

Considering that the same density of fish is detected by both vessels one can write:

$$C_{c.s.} \times M_{c.s.} = C_{f.n.} \times M_{f.n.} \qquad (2)$$

$$C_{c.s.} = \frac{M_{f.n.}}{M_{c.s.}} \times C_{f.n.} \qquad (3)$$

The expression $M_{f.n.}/M_{c.s.}$ is obtained during the intercalibration using two methods:

(a) by means of the linear regression between the values of integration (millimeters) registered on both vessels;

(b) comparing and finding the relation between the means fo the sums of the integrator output values obtained by both vessels surveying the same area.

During the intercalibration between "CORNIDE" and "NANSEN" the two vessels sailed over a layer of scattered sardines following the 40 meters isobath (fig. 2) They both covered 45 nautical miles (fig. 3). To calculate the intercalibration coefficient, only the data corresponding to scattered fish on the echograms were used, over a total length of 40 miles.

The intercalibration coefficient found by the method of linear regression is:

$$M_{c.s.} = 28.16 + 5.78\ M_{f.n.} \quad (4)$$

with correlation coefficient $r^2 = 0.78$ ($r = 0.88$)

If we take the actual ratio of the averages of all the measured values of M for both vessels:

$$M_{c.s.} = 6.50\ M_{f.n.} \quad (5)$$

the C values of both acoustic systems should be related as follows:

$$C_{c.s.} = \frac{C_{f.n.}}{6.50} \quad (6)$$

The conversion factor or density coefficient for the acoustic system of "NANSEN" is:

$$C_{f.n.} = 13.6 \text{ tons/mn}^2\text{/mm/mn}$$

for small pelagic fish with swim bladder and a standard length of 17 cm (Strømme , Saetersdal and Gjøsaeter, 1982).

Consequently:

$$C_{c.s._{17}} = \frac{13.6}{6.50} = 2.09 \text{ tons/mn}^2\text{/mm/mn} \quad (8)$$

A second series of calculations was made using only the values corresponding to the distance during which both vessels had been obviously sailing over identical concentrations (fig. 3, miles 1 to 26). The regression obtained between these values was:

$$M_{c.s.} = 69.25 + 4.79\ M_{f.n.} \quad (9)$$

with a correlation coefficient $r^2 = 0.92$ ($r = 0.96$)

Using the means relations of these values, neither the relation nor the resulting conversion factor varies considerably from the ones obtained before:

$$M_{c.s.} = 6.66\ M_{f.n.} \quad (10)$$

$$C_{c.s.} = \frac{C_{f.n.}}{6.66} \quad (11)$$

$$C_{c.s.} = 2.04 \text{ tons/mn}^2\text{/mm/mn} \quad (12)$$

Because of that it was decided to take as final conversion factor the one calculated in the first place (expression 8) because it was considered to represent a higher number of situations found during the survey.

3.2 Intercalibration between the R/V CORNIDE DE SAAVEDRA and the R/V NORUEGA

The intercalibration navigation took place on 28 August, 1982, on the continental shelf between Vigo and the border with the Portuguese territorial waters. The ships sailed 124 nautical miles over depths oscillating between 70 and 100 metres. The CORNIDE was the forward vessel and the echo integrators were reset every 10 minutes. Two integration channels were used this time. Channel A was situated following a plankton layer of variable density, between the limits of 15 and 40 metres (fig. 5). Channel B (40-70 metres) followed a layer of scattered mesopelagic fish, probably blue whiting or hake (fig. 6).

Intercalibration coefficients were calculated for the echo integrator outputs of both channels. For channel A the values obtained for each mile were used, with the exception of those in which adjustment of any of the instruments was made (fig. 7). For channel B, only the values obtained in the miles in which the presence of scattered fish was registered were used (fig. 9).

The instruments settings during the intercalibration are shown in Table I. They also represent for the NORUEGA and the CORNIDE the standard working conditions during the survey. The acoustic calibration of the NORUEGA had been performed three weeks before intercalibration. On the CORNIDE, it had been made four months before. An attempt to carry out new measurements on the CORNIDE was made, but rough weather made impossible the correct ubication of the standard target in the center of the acoustic beam. Performance data are shown in Table II.

3.2.1 Intercalibration over the plankton layer

Figure 7 (A and B) shows the correspondence between the values of the NORUEGA and the CORNIDE.

The intercalibration coefficient was the following, when using the linear regression method:

$$M_{c.s.} = 1.25 + 0.09\, M_{n.} \qquad (13)$$

with correlation coefficient $r^2 = 0.91$ ($r = 0.95$)

Comparing mean values of the echointegrator outputs:

$$M_n = 10.5\, M_{c.s.} \qquad (14)$$

3.2.2 Intercalibration over a layer of scattered fish

The correspondence between the values of the NORUEGA and CORNIDE is shown in fig. 9. The coefficient of intercalibration obtained by means of linear regression was:

$$M_{c.s.} = -0.11 + 0.11\, M_n \quad \text{(fig. 10)} \qquad (15)$$

with correlation coefficient $r^2 = 0.96$ ($r = 0.98$)

Comparing mean values of the echo integrator outputs:

$$M_n = 9.5\, M_{c.s.} \qquad (16)$$

IV. DISCUSSION

Intercalibrations between research vessels with echo integrators is needed occasionally in order to calculate the density coefficient C for a vessel starting from the value of another one. For the execution of multi-ship surveys the transformation of the output values of all the integrators into the units of one ship is convenient because the data are directly comparable and distribution charts of relative abundance of the surveyed stocks can be drawn in the same units.

One of the intercalibration methods most commonly used is the joint navigation of two research vessels. Its advantages over other methods like using standard spheres have already been described (Rottingen, 1982) and can be summarized in that the working conditions and the type of targets used during the intercalibration are the same as those used during the survey. The main disadvantage is that both vessels do not sail exactly over the same targets during intercalibration.

The density coefficient (C) for the R/V Dr. FRIDTJOF NANSEN system was calculated for small pelagic fish. The intercalibration between this vessel and the R/V CORNIDE DE SAAVEDRA was carried out over a layer of variable density of scattered sardines. The intercalibration between the CORNIDE and the NORUEGA could not be fulfilled with regard to this same species. The only available targets were a plankton layer and a layer of mesopelagic fish as described above. The coefficient of intercalibration for that fish was taken as definitive. It is possible that if intercalibration had been executed on sardines the calculated coefficient might have somewhat changed.

However, the values obtained for targets such as plankton and mesopelagic gadiformes with a target strength that must be very different, hardly differ by 10 percent. This allows to think that the intercalbration coefficient calculated cannot be very different from that which could have resulted if the navigation had taken place over a layer of scattered sardines.

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	CORNIDE	Dr. FRIDTJOF NANSEN	NORUEGA
ECHO SOUNDER	EK 400	EK-S	EK-S
Frequency	38 kHz	38 kHz	38 kHz
Transducer	30x15 ceramic	30x30 ceramic	30x30 ceramic
Transmitter	1/1 (2500 W)	EXT (2500 W)	1/1
TVG/Gain	20 log R/O dB	20 log R/-20 dB	20 log R/O dB
Pulse length	1.0 ms	0.6 ms	0.6 ms
Bandwidth	1 kHz (DrFN) 3.3 kHz (Noruega)	3 kHz	3 kHz
INTEGRATOR	QD	QM - MK II	QM - MK II
Gain	0 dB x 100	20 dB x 10	20 dB x 10
Threshold	10 mV	1	1

Table I. Instruments settings on the research vessels during the intercalibration navigation.

	CORNIDE	Dr. FRIDTJOF NANSEN	NORUEGA
SL + VR	131.7 dB	137.6 dB	130.9 dB
$C_{tvg} = 20 \log r + 2$	64.6 dB	64.5 dB	64.5 dB
Pulse length	1.0 ms	0.6 ms	0.6 ms
Bandwidth	3 kHz	3 kHz	3 kHz
10 log Ψ	-18.0 dB	-21.4 dB	-21.4 dB
C_1	-44.9 dB	-57.7 dB	-49.9 dB
Date	March 82	February 82	August 82

Table II. Performance data from the acoustic calibration on the three vessels.

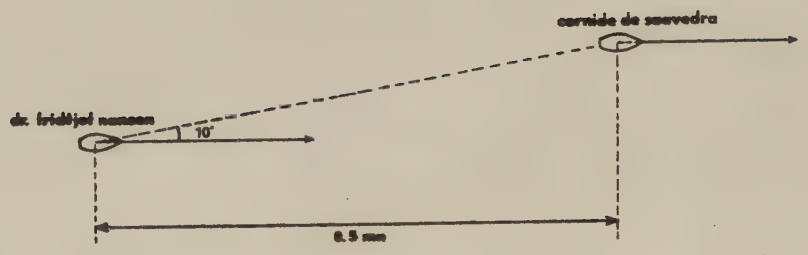

Fig. 1 Sailing disposition of research vessels during intercalibration NORUEGA was astern vessel in the second intercalibration

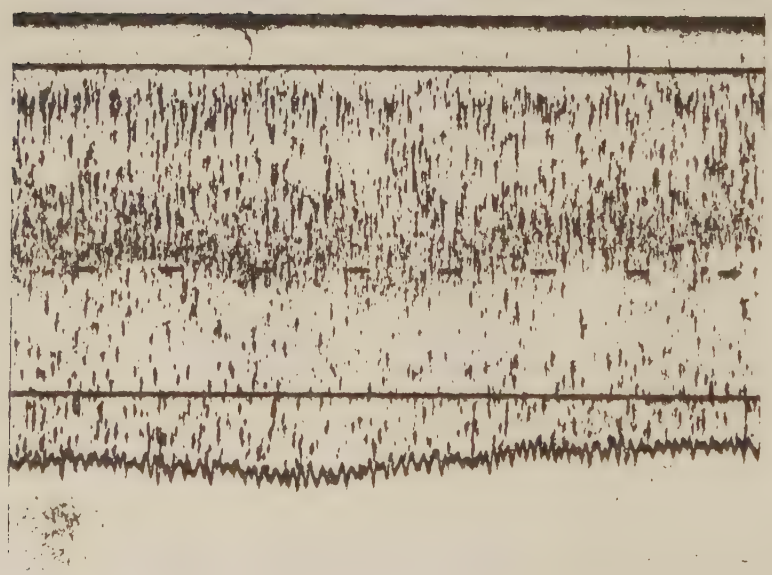

Fig. 2 Sardine scattered layer observed in the echograms during the intercalibration between NANSEN and CORNIDE

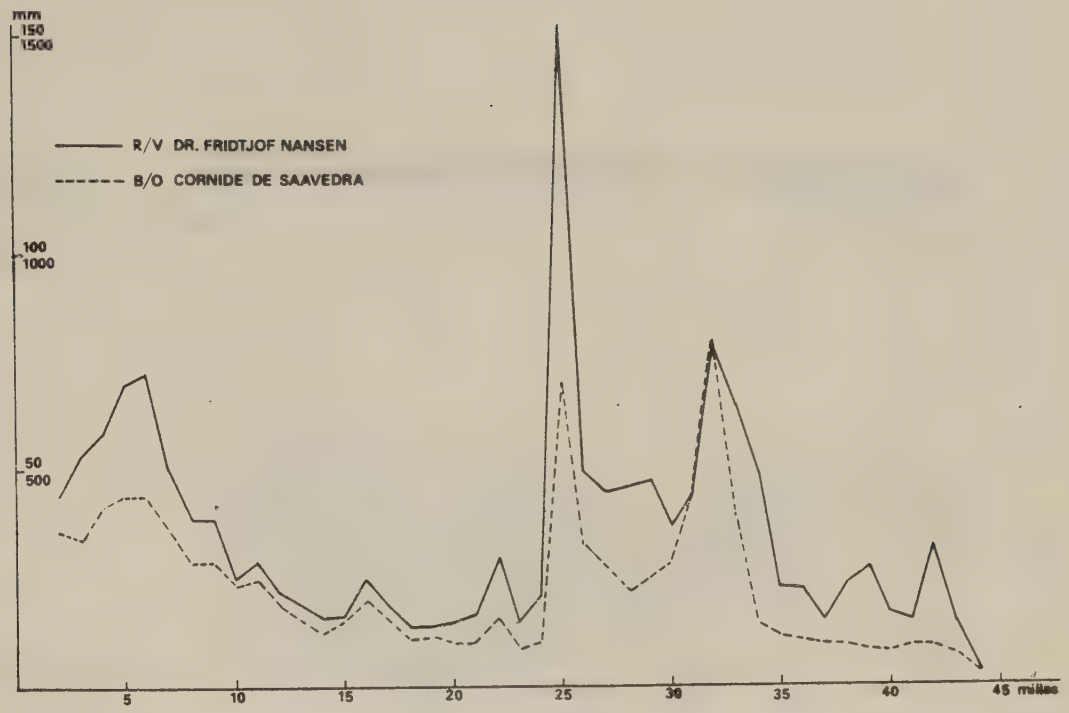

Fig. 3 Correspondence of the output integrator values of NANSEN and CORNIDE during intercalibration.

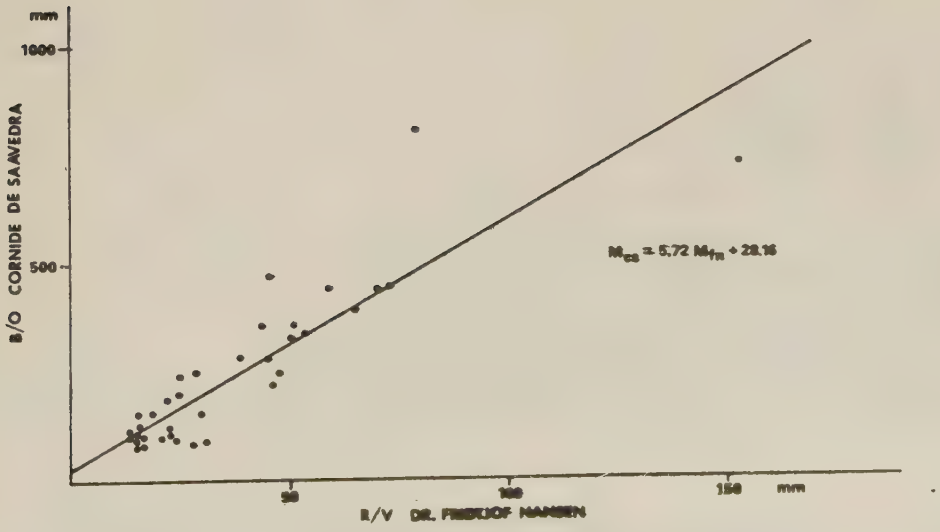

Fig. 4 Results of the intercalibration. NANSEN and CORNIDE echo integrators output values.

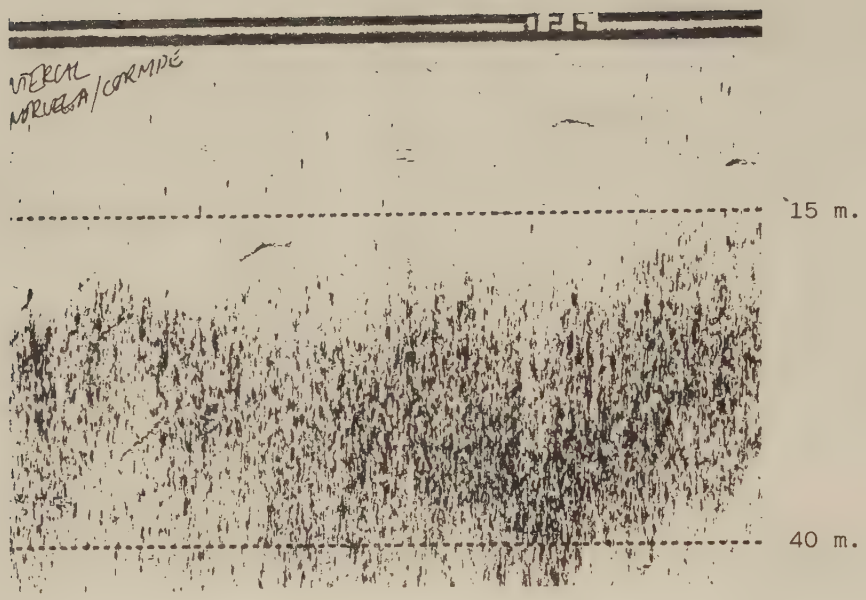

Fig. 5 Intercalibration between NORUEGA and CORNIDE. Plankton layer registered on the echograms. Channel A.

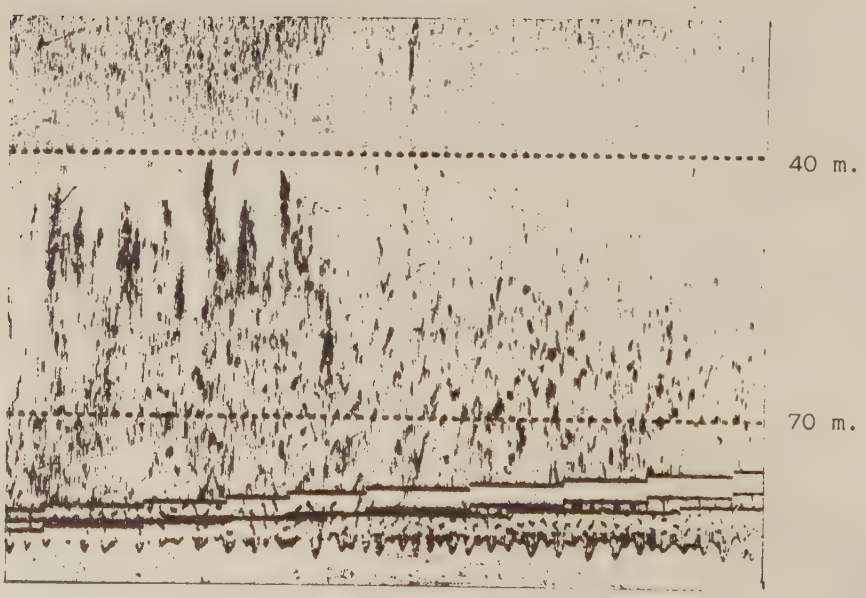

Fig. 6 Intercalibration between NORUEGA and CORNIDE. Mesopelagic fish. Channel B.

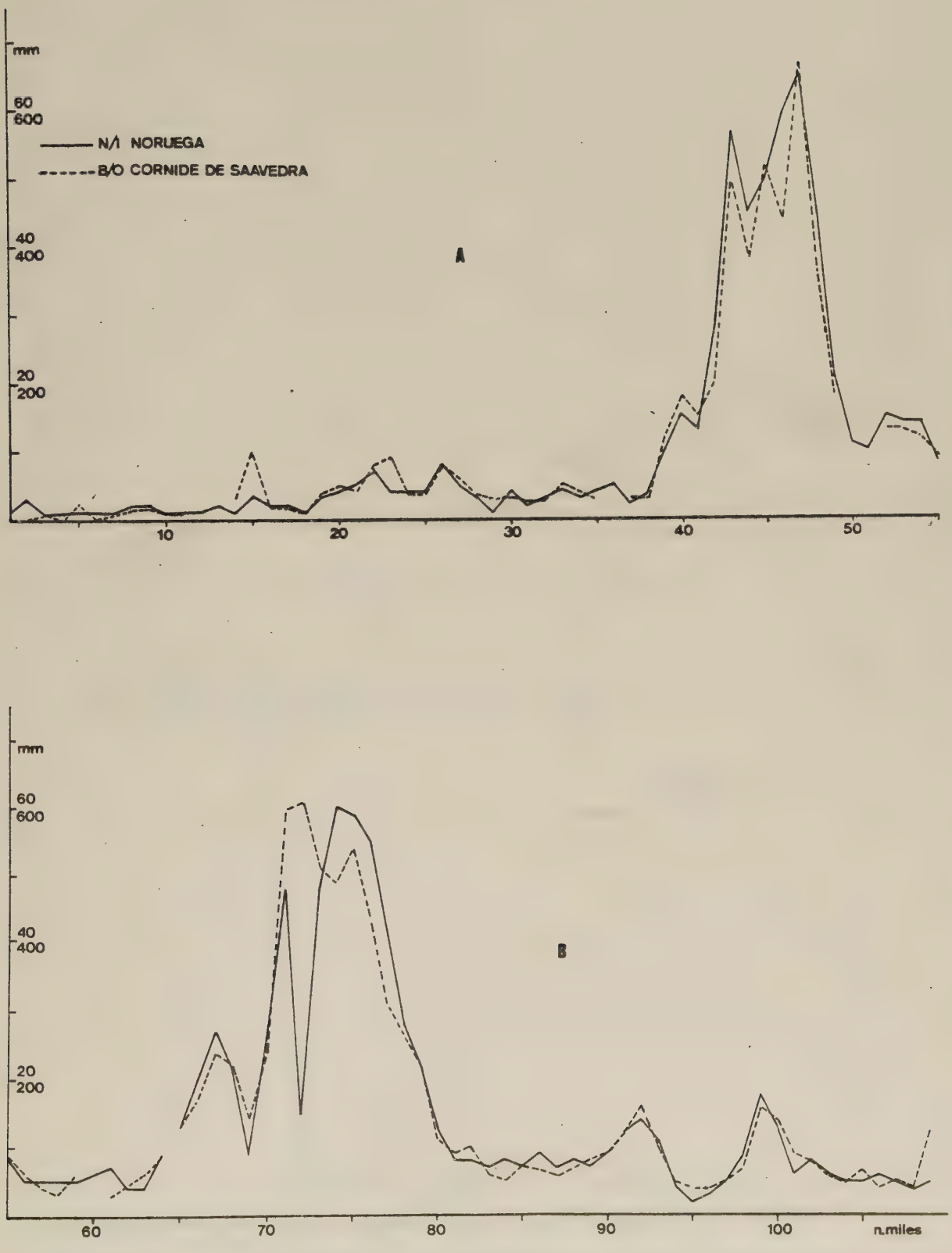

Fig. 7 Correspondence of the output integrator values of NORUEGA and CORNIDE. A: miles 1-55. B: miles 56-105. Discontinuities in lines correspond to instrument adjustments. (') Integrator off. Value not used in calculations.

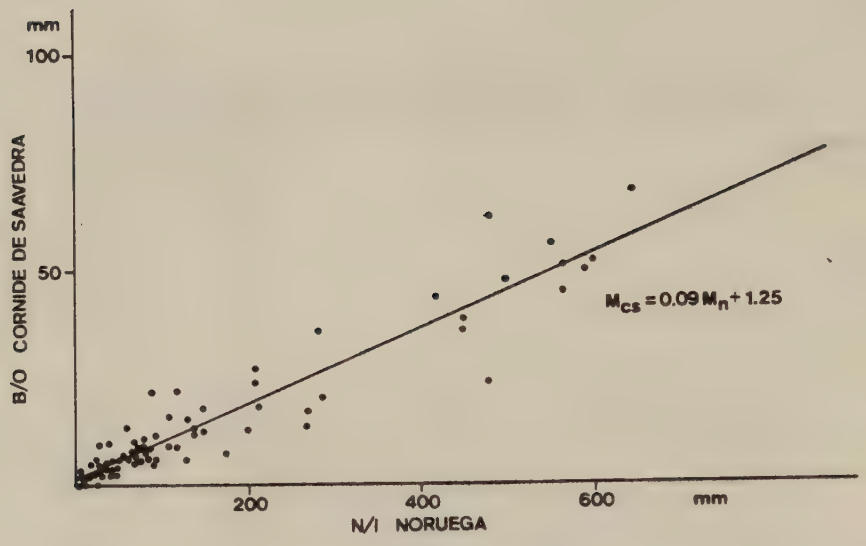

Fig. 8 Results of intercalibration between NORUEGA and CORNIDE. Echo integrators output values.

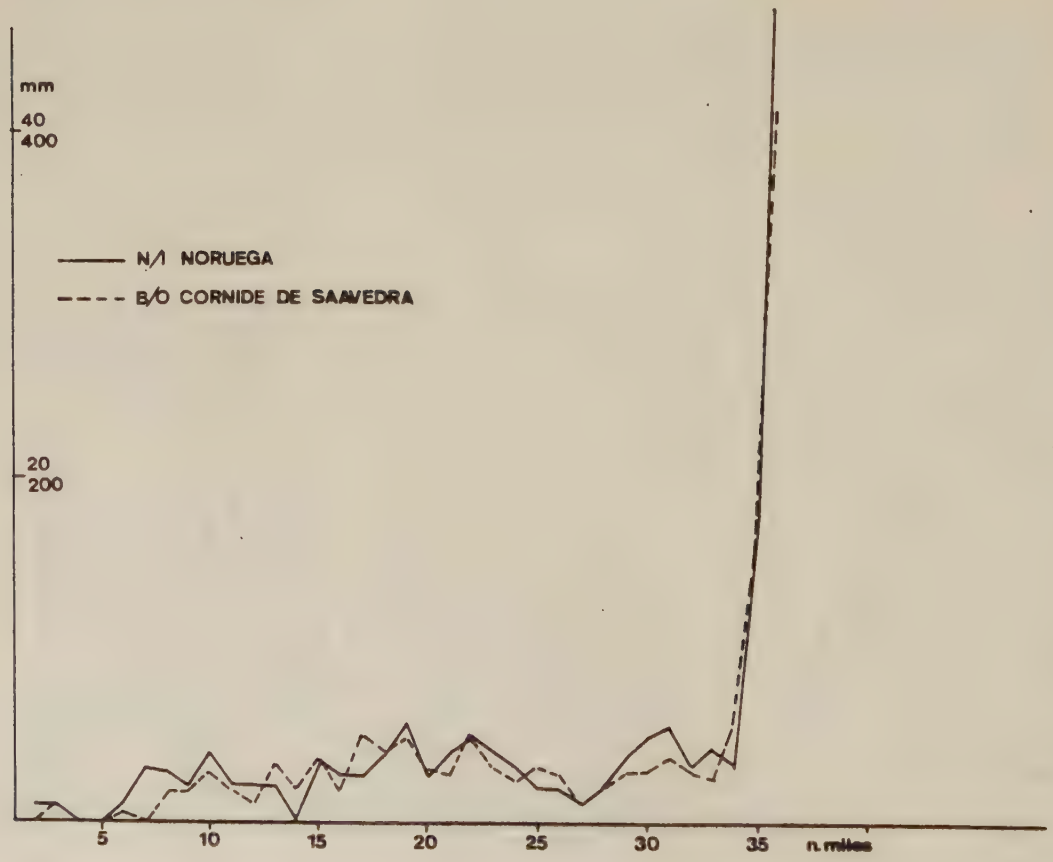

Fig. 9 Correspondence of the output integrator values of NORUEGA and CORNIDE during intercalibration. Channel B (fish layer)

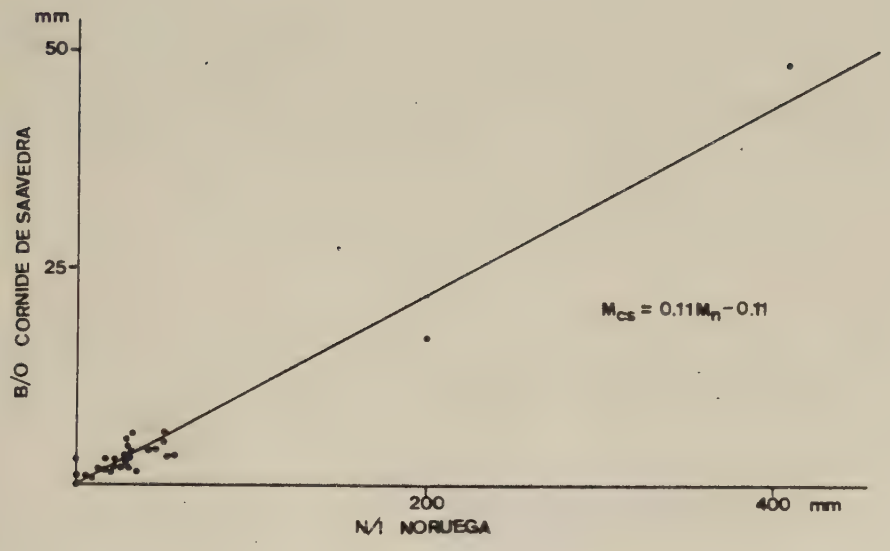

Fig. 10 Results of intercalibration between NORUEGA and CORNIDE. Channel B (mesopelagic fish). Echo integrator outputs.

APPENDIX/ANNEXE N

PRELIMINARY ACOUSTIC ASSESSMENT OF THE COASTAL PELAGIC FISH STOCKS OF THE SPANISH ALBORAN SEA, WITH SPECIAL REFERENCE TO THE SARDINE (MAY 1982)

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I. INTRODUCTION

Since the seventh meeting of the GFCM Working Party on Resource Appraisal and Fishery Statistics (Rome, January 1978), assessment by acoustic methods of the stocks of pelagic coastal fish in the Alboran sea has been recommended (FAO, Fisheries Report 204). This project should have been undertaken in collaboration between Morocco and Spain and recommendations for this have been made practically at every subsequent meeting of the GFCM. Finally in 1982 the AL SAREV-82 survey was carried out between 8 and 22 May 1982 by the R/V CORNIDE DE SAAVEDRA of the Instituto Español de Oceanografía with, among other aims, the above-mentioned assessment on the spanish waters.

At the time of the survey the Spanish vessel could only work in the North of the Alboran sea (Apanish EEZ). Nevertheless the R/V IBM SINA of the Instot scientifique des pêches of Morocco made in the same period (May, 1982) the acoustic assessment of coastal pelagic stocks of the South of the Alboran sea (Moroccan EEZ) which will allow to complete the assessment. This paper is a summary of the biomass assessment made during the survey L ASAREV-82.

II. MATERIAL AND METHODS

The R/V CORNIDE DE SAAVEDRA is 50 meters long; its tonnage is 1 000 GRT. It is equipped with two echosounders Simrad EK-400 (38 kHz and 120 kHz) and with a digital echo integrator simrad QD. It is also equipped with an Elac sonar, a calibration unit corresponding to the SIMRAD equipment ementioned, a pelagic trawl that can fish at four knots with a vertical opening of 10 meters and a netsounder (SIMRAD FR-500) with cable.

The survey took place in the north of the Alboran sea (Spanish EEZ). The sampling area was divided into 7 sectors of 30' of longitude and 4 strata were introduced in each sector for the depth stratification (0-30, 30-100, 100-200 and 200-500 meters).

The trip covered the sampling area from East to West, making perpendicular tracks to the coast and arriving to the depth line of 500 meters. Afterwards the sailed from West to East in zig-zag but this time arriving only to a depth of 200 meters (figures 1, 2 and 3).

Twelve pelagic trawl stations were done to identify the echoes, of which eleven were positive. The results of the trawl stations were normalized to an hour. L ength sampling of the total catch was done and biological sampling of the total catch was done and biological sampling of the sardine (length, sex and stage of maturity and otolith extraction for age reading).

During the survey a group of ictioplanctonic and hydrological stations were covered to obtain complementary knowledge of the working area. The results form these stations are not given in this paper.

During the AL SASEV-82 survey an intercalibration was done with the R/V Dr. FRIDTJOF NANSEN ans described above in Appendix M to obtain the C value.

The allocation of densities by length groups was done accordint to the method described by Nakken and Dommasnes (1975), using the expression:

$$i = \frac{k_i M}{\frac{k_i}{C_i}}$$

Where:

f_i is the density of the i-th length class
k_i is the proportion of this length class of the total catch
is the reading of the echointegrator in mm and
C_i is the calibration constant C of each length class, which has been calculated from

$$C_i = C_{cs\ 17\ cm}\ \frac{l_i}{17}$$

$C_{cs\ 17cm}$ was determined from the intercalibration experiment to be 2.09 t/mm²/mm/nm (see Appendix M), therefore: $C_i = 2.09 \frac{l_i}{17}$

The transformation of the sardine abundances from length-classes to age-classes was done with the age-length key obtained on the same survey from the reading of the otoliths collected during the biological samplings.

All the calculations were done with the programme EL ACU 5, specially edited for this job in BASIC language, and a HP-9845 A computer (Annex 1).

The distribution of the relative densities of pelagic fish in the sampled area is based on the integrator outputs for each mile sailed and drawing isolines after having smoothed the area with the running mean method taking successive groups of five miles.

Finally, the abundance of sardine expressed in tons by age class was transformed into an abundance index in numbers by dividing the amount in tones by the third power of the average length of each age class, with which a sort of catch curve could be made (Fig 5)

The pelagic trawl stations considered to be valid samples were allocated to stata and sectors as indicated in Table 1.

III. RESULTS AND DISCUSSIONS

Table 2 summarizes the characteristics and the results of the valid pelagoc trawl . These results, combined with the reading of the echointegrator were used to produce the biomass figures by species presented in Table 3. The distribution of the density of all pelagic species is given in figure 4.

The Alboran sea, grosso modo, can be divided into three areas defined by the different general hydrological conditions. Sector 1 and the western part of sector 2 are characterized by cold waters coming from the upwelling of intermediate layers. The eastern part of sector 2 and the sectors 3 and 4 are characterized by the presence of waters coming from the Atlantic and by occasional upwelling areas due to diverging processes or eastern winds. Finally the sectors 5, 6 and 7 would be of typical Mediterranean water (Fig. 1, 2 and 3). Capros aper only appears in the sectors 1 and 2 where its presence is predominant (Table 3). The most abundant pelagic species in the Alboran sesa is the bogue (Boops hoops). One also sees that the rpesence of this species diminishes in the sectors close to the Gibraltar straits (1 and 2), where Capros aper and anchovy are the most abundant species. It should be mentioned here that the bogue appars in the echo-sounder registrations forming peculiar dense schools of large size in mid-water.

Spicara sp. , a species of commercial interest, is of relative abundance from sector 4 eastward.

The most recent data of catches of pelagic species by purse-seiners in the Spanish EEZ checked by the IEO, are those of 1978: they represent 18 000 tons, 5 000 of which are sardines and another 5 000 anchovies (CPPM data).

In an assessment of the sardine stocks of the Alboran sea made during the Sixth Technical Consultation on stock assessment on the balearic and Gulf of Swin statistical divisions, December 1979, using a production model and based on the Moroccan cpue, the MSY was estimated at 21 000/22 000 tons, of which 15 000 tons would correspond to the Moroccan area and 6 000/7 000 tons to the Spanish area.

Table 4 gives the abundance by age-classes of sardines by sectors derived from the length-age key obtained from the age reading done during the survey (Table 5). These readings were done in accordance with teh standardized CECAF/COPACE method (1978) for Sardina pilchardus in ths area. In general, the structure of the sardine otoliths of the Alboran sea and other Mediterranean areas, presents a different growth pattern from that of the Atlantic sardine, which makes the interpretation of the annual rings mdifficult (IEO, 1982). For this reason, the average length obtained for each age-class used in the results may have to be revised when the growth of the species in the sampled area is defined more precisely.

The predominent presence of age-class of sardine in each sector indicates a distribution of juveniles that is not in agreement with the results of the ichthyo plankton samples collected during AL SAREV-82 and previous observations (Oliver, 1955).

Class I appears extremely weak in every sector, but this result could as above be a simple sampling error.

Figure 5 shows the catch curve traced over the abundance indexes of sardine corresponding to the ages 2 and 6. An approximate Z value equal to 0.75 was obtained by drawing a regression line by eye.

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Strata / Sector	1	2	3	4
1	10+14	12+13+ +14	12	12
2	10+14	9+12+ +13+14	9+12+ +13+14	9+12
3	10	7+8+9	7+9	7+9
4	10	7+8+9	7+15	7+15
5	10	7+8+15	7+15	7+15
6	5+10	5+6+15	6+15	6+15
7	5+10	5+6+15	6+15	6+15

Table 1. - Numbers of the valid pelagic trawl stations considered to be representative for the sectors and strata as indicated.

St. no.	Bottom depth (m)	Gear depth (m)	Time start	Total catch (Kg)	Catch per hour (Kg)	Dominant species (%)						
						sardine	Anchovy	Horse mackerel	Bogue	Mackerel	Pagellus sp.	Capros aper
5	44	20	24.00	5	5	48	-	17	34	-	-	-
6	76		23.00	11	10	-	-	58	9	-	11	-
7	80	60	21.00	53	26	3	-	35	37	24	-	-
8	55	15	24.00	3	3	29	8	38	19	-	-	-
9	58	34	09.00	6	4	-	-	-	100	-	-	-
10	24	10	23.00	32	32	17	-	2	67	-	15	-
11	80	10	01.00			x	-	x	x	-	-	-
12	50	15	23.00	240	260				x			100
13	54	25	22.00	12	14	52	9	-	21	-	9	9
14	40	10	01.00	5200	4330	x	-	x	-	-	-	100
15	53	30	21.00	6	4	20	1	10	32	2	25	-
16	30	25	07.00									x

Table 2. - Characteristics of the pelagic trawl stations and dominant species in % of the total catch.

	SARDINE	BOGUE	HORSE MACREREL	MACREREL	ANCHOVY	Capros aper	Spicara sp.	Pagellus sp.	TOTAL
SECTOR 1 Estepona	121	30	80	0	6860	13470	0	6	20567
SECTOR 2 Marbella	106	32	73	0	7938	5568	0	7	13724
SECTOR 3 Malaga	18370	19886	8674	1836	0	0	0	152	48918
SECTOR 4 Almuñecar	5692	6735	4891	1033	0	0	32	69	18452
SECTOR 5 Adra	2405	3201	7947	1671	25	0	14	128	15391
SECTOR 6 Roquetas	10739	9436	9491	0	0	0	2331	2419	34417
SECTOR 7 Almeria	5958	5519	5290	0	0	0	1289	1366	19422
TOTAL	43392	44839	38447	4540	14823	19038	3666	4147	170891

Table 3. - Abundance of each species by sector in metric tonnes.

Sector / Age class	1	2	3	4	5	6	7	Total
0	91.0	72.1	9240.3	2784.2	1870.7	8454.2	4682.7	27195.2
I	10.0	11.6	113.1	39.7	21.1	270.0	146.0	611.5
II	12.8	14.6	2039.9	661.0	152.1	966.2	542.3	4388.9
III	6.9	7.9	2621.4	842.3	170.0	891.3	501.0	5040.8
IV	0.1	0.1	1778.2	560.4	87.2	133.6	74.5	2634.1
V	0.0	0.0	1032.1	323.9	47.5	19.5	9.0	1432.0
VI	0.0	0.0	729.6	227.0	25.7	0.3	0.5	983.1
VII	0.0	0.0	321.6	101.1	16.0	4.0	2.1	448.1
VIII	0.0	0.0	493.4	152.9	14.7	0.3	0.5	661.8
Total	120.8	106.3	18369.6	5692.5	2405.0	10739.4	5958.6	43392.2
0 class (%)	75.1	67.8	50.3	48.9	77.8	78.7	78.6	62.7

Table 4. - Abundance of sardine by sector and age class. Unit = ton.

Age class / length	0	I	II	III	IV	V	VI	VII	VIII	n
10	100									3
11	(100)									
12	100									3
13		100								2
14		93	7							14
15		39	44	17						18
16		14	50	36						28
17			41	52	7					27
18			29	42	29					7
19			22	11	23	11	11	11	11	9
20			8	17	25	42		8		12
21				33	33		34			3
22							50		50	2
23										
24										
Average length	15.4	16.9	17.4	18.8	19.8	20.8	19.5	20.7		

Table 5. - Age/Length key of sardine.
Percentage in brackets are estimated.

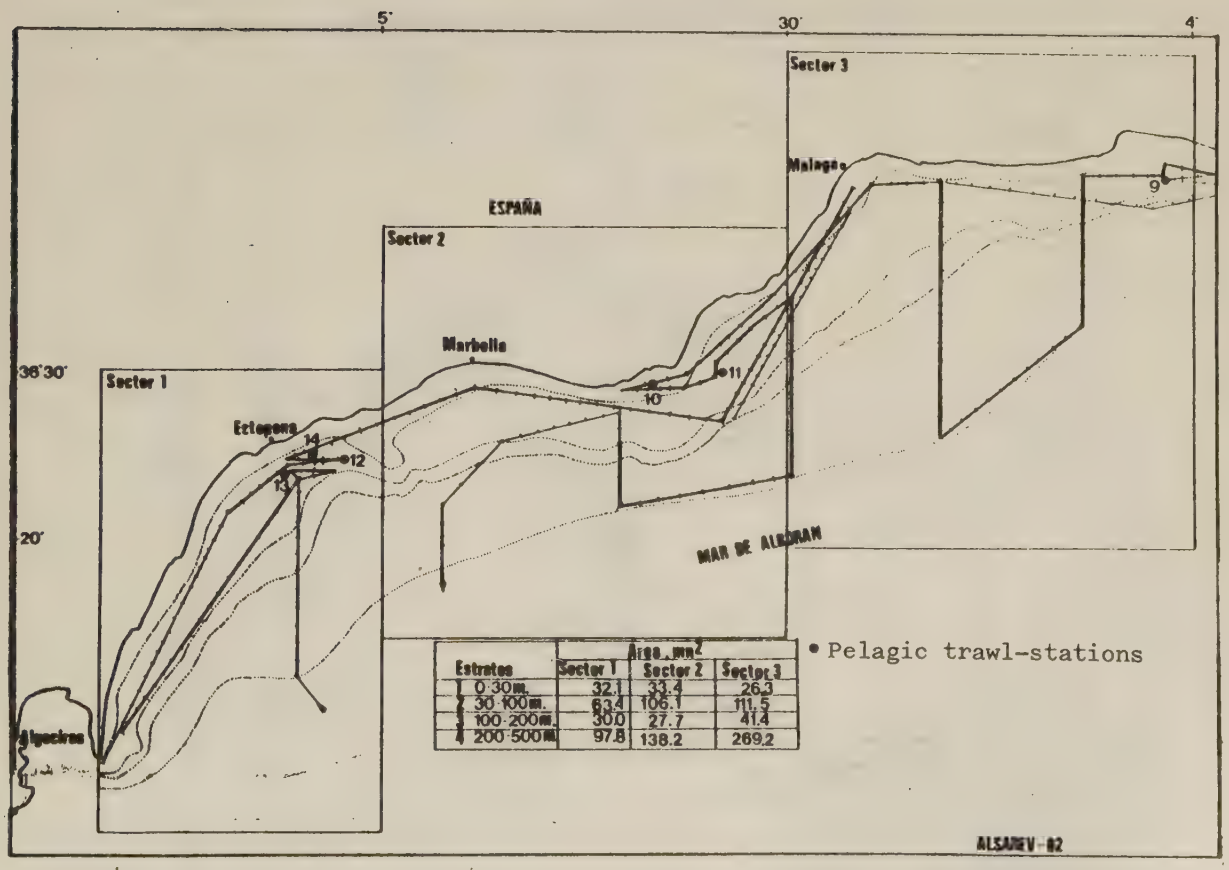
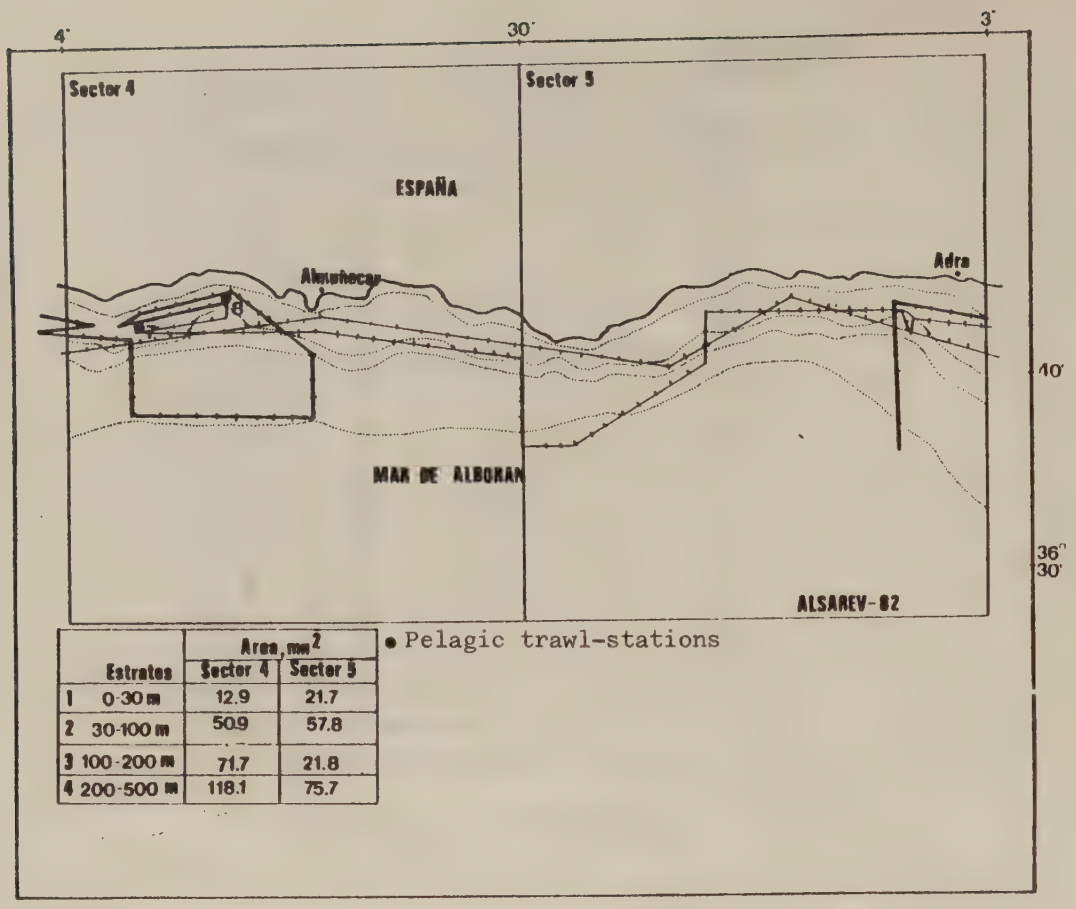
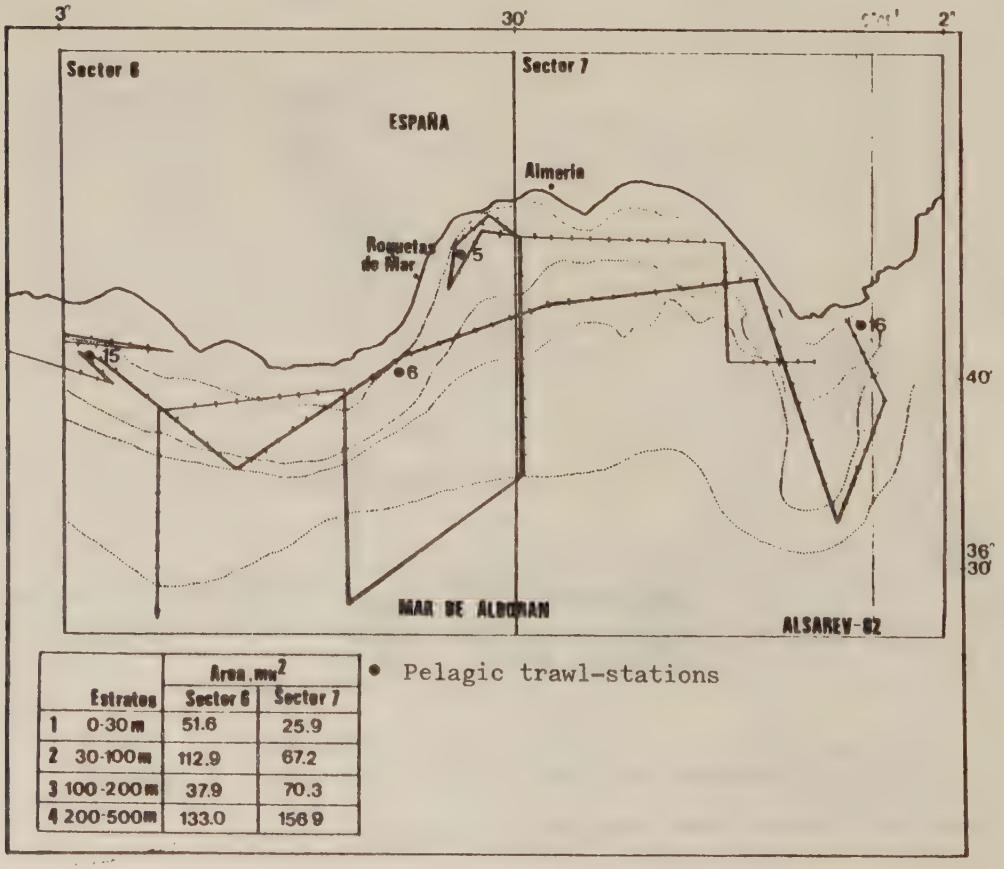


Fig. 1 - Tracks and pelagic trawl stations in sectors 1, 2 and 3.



Estratos	Area, mm² Sector 4	Sector 5
1 0-30 m	12.9	21.7
2 30-100 m	50.9	57.8
3 100-200 m	71.7	21.8
4 200-500 m	118.1	75.7

Fig. 2 - Tracks and pelagic trawl stations in the sectors 4 and 5.



Estratos	Area, mm² Sector 6	Sector 7
1 0-30 m	51.6	25.9
2 30-100 m	112.9	67.2
3 100-200 m	37.9	70.3
4 200-500 m	133.0	156.9

Fig. 3 - Tracks and pelagic trawl stations in the sectors 6 and 7.

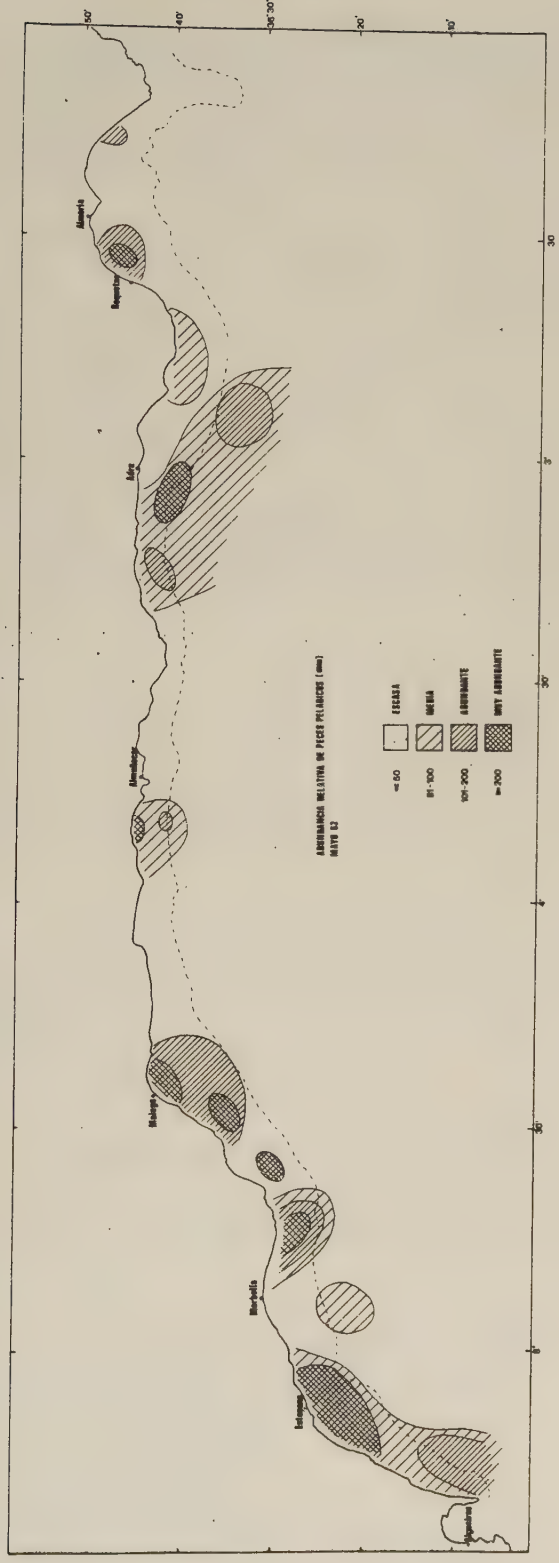


Fig. 4 - Density distribution of pelagic fish in the Spanish Alboran sea.

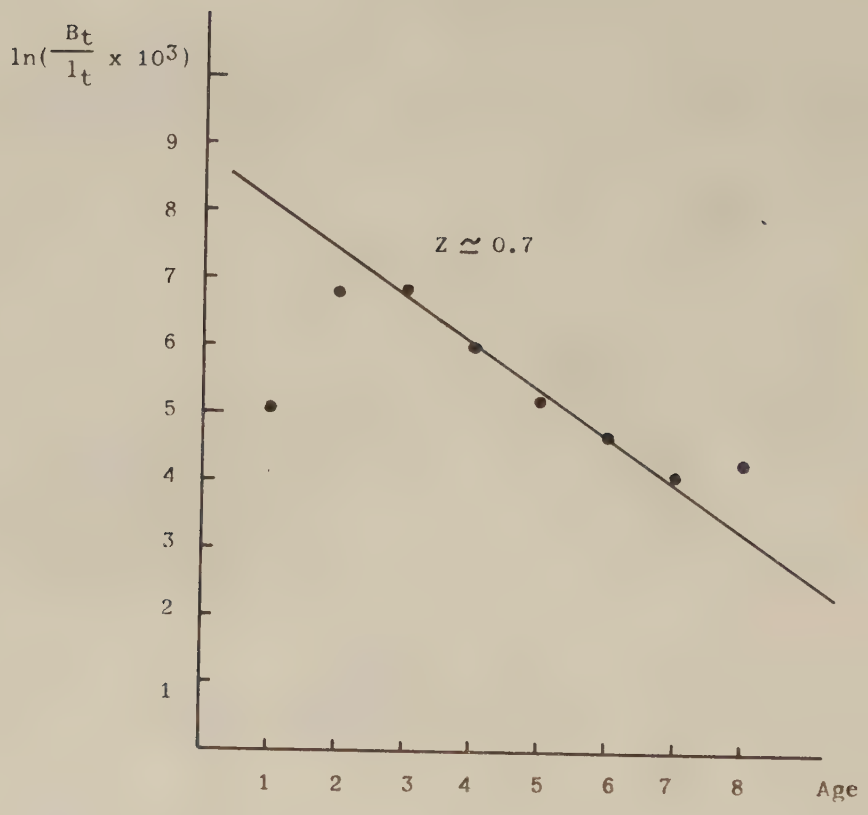


Fig. 5 - Sardine catch curve

ANNEX 1

PROGRAMME FOR COMPUTER HP-9845 B

INPUTS: Length distribution of species in the samples; Coefficient C for a given length; Values of integrator in mm; Area of the surveyed stratum in square miles.

OUTPUTS: Calculated C for each length; Estimated density of fishes by species and length; Estimated abundance in tons by species and length.

```
10    !     ******  ELABORACION DE DATOS DE CAMPANYAS DE ACUSTICA ******
20    !
30    DIM Ca$[15]
40    SHORT H(4:30,10),S(10),R(4:30,8),S2(8),B(4:30,8),Sb(8)
50    INPUT "CAMPANYA ?",Ca$
60    INPUT "SECTOR ?",Se$
70    INPUT "ESTRATO ?",Es$
80    INPUT "ESCRIBE EL RANGO DE TALLAS (Talla menor, talla mayor)",Li,Lf
90    FOR I=Li TO Lf
100      PRINT "TALLA";I;LIN(19)
110      INPUT "DATOS PARA ESA TALLA DE LAS ESPECIES  A  B  C  D  E  F  G",H(I,1
),H(I,2),H(I,3),H(I,4),H(I,5),H(I,6),H(I,7)
120      H(I,8)=H(I,1)+H(I,2)+H(I,3)+H(I,4)+H(I,5)+H(I,6)+H(I,7)
130   NEXT I
140   MAT S=CSUM(H)
150   INPUT "ESCRIBE LA C PARA 17 cm",H(17,10)
160   FOR I=Li TO Lf
170      H(I,9)=H(I,8)/S(8)
180      H(I,10)=H(17,10)*(I/17)
190   NEXT I
200   MAT S=CSUM(H)
210   INPUT "ESCRIBE LOS mm DE INTEGRACION",M
220   Sum=0
230   FOR I=Li TO Lf
240      Sum=Sum+H(I,9)/H(I,10)
250   NEXT I
260   FOR I=Li TO Lf
270      R(I,8)=H(I,9)*M/Sum
280      FOR J=1 TO 7
290      ON ERROR GOTO 310
300         R(I,J)=R(I,8)*H(I,J)/H(I,8)
310      NEXT J
320   NEXT I
330   MAT S2=CSUM(R)
340   !                  PRESENTACION DE LOS RESULTADOS
350   PRINTER IS 0
360   PRINT "DISTRIBUCION DE TALLAS POR ESPECIES - CONSTANTES DE CALCULO"
370   PRINT Ca$
380   PRINT "SECTOR  ";Se$
390   PRINT "ESTRATO  ";Es$
400   PRINT
410 PRINT "I";TAB(8);"A";TAB(15);"B";TAB(22);"C";TAB(29);"D";TAB(36);"E";TAB(43)
;"F";TAB(50);"G";TAB(57);"tot";TAB(64);"k";TAB(68);"c"
420   PRINT RPT$(CHR$(236),75)
430   IMAGE 2D,X,7(6D,X),6D,2(X,2D.2D)
440   IMAGE 2D,X,7(X,4D.2D),X,5D.2D
450   IMAGE 3A,7(X,4D.2D),X,5D.2D
460   IMAGE 3A,7(6D,X),6D,2(X,2D.2D)
470   FOR I=Li TO Lf
480      PRINT USING 430;I;H(I,1);H(I,2);H(I,3);H(I,4);H(I,5);H(I,6);H(I,7);H(I,
8);H(I,9);H(I,10)
490   NEXT I
500   PRINT
510   PRINT USING 460;"Tot";S(1),S(2),S(3),S(4),S(5),S(6),S(7),S(8),S(9)
520   PRINT LIN(2)
```

```
530   PRINT "DENSIDADES POR ESPECIE,POR TALLA Y TOTALES"
540   PRINT Ca$
550   PRINT "SECTOR  ";Se$
560   PRINT "ESTRATO  ";Es$
570   PRINT
580 PRINT "1";TAB(9);"A";TAB(17);"B";TAB(25);"C";TAB(33);"D";TAB(41);"E";TAB(49)
;"F";TAB(57);"G";TAB(65);"Tot"
590   PRINT RPT$(CHR$(236),70)
600   FOR I=Li TO Lf
610      PRINT USING 440;I;R(I,1);R(I,2);R(I,3);R(I,4);R(I,5);R(I,6);R(I,7);R(I,
8)
620   NEXT I
630   PRINT
640   PRINT USING 450;"Tot";S2(1),S2(2),S2(3),S2(4),S2(5),S2(6),S2(7),S2(8)
650   PRINT LIN(2)
660   PRINT "ABUNDANCIAS POR ESPECIE,POR TALLA Y TOTALES"
670   PRINT Ca$
680   PRINT "SECTOR  ";Se$
690   PRINT "ESTRATO  ";Es$
700   PRINT
710   INPUT "ESCRIBE EL AREA DEL SECTOR EN MILLAS CUADRADAS",Ar
720   MAT B=R*(Ar)
730   MAT Sb=CSUM(B)
740   IMAGE 2D,7(X,5D.2D),X,6D.2D
750   IMAGE A,X,6D.2D,X,6(5D.2D,X),6D.2D
760   PRINT "L";TAB(8);"A";TAB(17);"B";TAB(26);"C";TAB(35);"D";TAB(44);"E";TAB(5
3);"F";TAB(62);"G";TAB(72);"Tot"
770   PRINT RPT$(CHR$(236),75)
780   FOR I=Li TO Lf
790      PRINT USING 740;I;B(I,1);B(I,2);B(I,3);B(I,4);B(I,5);B(I,6);B(I,7);B(I,
8)
800   NEXT I
810   PRINT
820   PRINT USING 750;"T",Sb(1),Sb(2),Sb(3),Sb(4),Sb(5),Sb(6),Sb(7),Sb(8)
830   PRINT LIN(2)
840   INPUT "OTRO SECTOR O ESTRATO DIFERENTES ? (S/N)",R$
850   IF R$="N" THEN 890
860   INPUT "SECTOR ?",Se$
870   INPUT "ESTRATO ?",Es$
880   GOTO 210
890   PRINTER IS 16
900 Fin:  END
```

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